PRODUCTIVITY CHANGE IN THE BRAZILIAN AGRICULTURAL SECTOR

BY

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Aos meus pais,

Joao e Josefa

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The purpose of this study was to measure and to improve the understanding of growth in total factor productivity in the agriculture of Brazil and its major regions, the South and the Northeast. Regional patterns of input substitution and usage were also estimated. The concept of value added as a restricted profit function was used in the analysis for the country, and a cost function approach was used in the regional analysis. Elasticities of value added, derived demand for intermediate inputs, and shadow prices were estimated for the country.

An attempt was made to relate yearly change in total factor productivity to variables representing agricultural credit and exports. For the regions, elasticities of substitution between inputs, own and cross-price elasticities were estimated.

During the period 1950-1976 value added grew at a rate of 3.1 per cent. The share of the primary inputs was 2.0 per cent. Total factor productivity was, therefore, the residual of 1.1 per cent. Estimated elasticities of value added with respect to the normalized price of fertilizers and land had unexpected signs, they were 0.33 and -1.44, respectively. Elasticities with respect to labor and capital were 1.49 and 0.64, respectively. The estimated elasticity of demand for fertilizers with respect to own price was -0.70.

Labor was the only input to have a negative relationship to its estimated shadow price. The shadow price functions showed substitutability among all primary inputs. Exports had a greater influence on productivity than credit.

The Northeast experienced a small and negative growth in productivity, during the period 1960-75. The growth in the South was also small but positive. Capital and labor were estimated to be substitutes in both regions. Capital and land were substitutes in the South and complements in the Northeast. Land and labor were complements in the South but substitutes in the Northeast.

Estimated own-price elasticities indicated an elastic demand for capital in both regions, an inelastic demand for labor in the South and an unitary elasticity for labor in the Northeast. For land, the demand in the South was elastic and for the Northeast the sign was inconsistent.

These results imply a growing duality between the two regions with the Northeast lagging in efficiency relative to the South.

CHAPTER I

INTRODUCTION

Brazil is a large country; it ranks sixth in the world in population (125 million), fifth in geographic area (3,286,479 square miles), tenth in GNP (U.S. $ 214,850 million in 1979), and its per capita income in 1978 was U.S. $ 1,523.

Brazil has a strong comparative advantage in the production of agricultural and mining products. In 1980 it was the fifth largest agricultural exporter in the world with exports of $ 9 billion. The country ranks first in the production of coffee, and second in the production of soybeans, cocoa, oranges and sugar. Other major crops are potatoes, corn, rice and cotton. Although the country is still a net importer of wheat, production is increasing rapidly. It has the world's fourth largest number of cattle, with over one million head, and timber reserves are the largest in the world.

Brazil also has a large and diversified endowment of mineral resources. The country ranks first in the export of iron-ore and fourth in reserves. Brazil is also the world's third largest producer of manganese and is expected to become a major producer of bauxite and aluminum, due to large reserves of bauxite in the Amazon region and growing hydroelectric capacity. Other important commercial minerals are

niobium (a rare metal of the vanadium family), berylium and uranium. The reserves of uranium are presently estimated at 11,000 metric tons.

The country has large deposits of phosphate. These deposits have been estimated at 140 million tons with an additional probable 350 million tons of soluble phosphate which can be directly applied as fertilizer. Gold, tin, nickel, zinc, copper, chronite, potassium and gemstones have good promise for commercial exploitation in the eighties.

Although Brazil has a relatively large industrial base, the country is deficient in overall energy production. Oil production is presently about two hundred thousand barrels per day with domestic consumption at about one million barrels per day; therefore, 80 per cent of the consumption is imported. Indigenous energy sources are being developed from hydroelectric power and alcohol (from sugarcane).

Physical and economic inequalities pervade the main regions of the country (Fig. 1). The South,[1] encompassing all the states south of the Northeast region and favored by climate and resources, has 75 per cent of the population and produces about 75 per cent of farm goods and 80 per cent of industrial output. Coffee, soybeans, wheat and other important crops are located in this region.

The Northeast region is a semiarid scrubland, heavily settled, and poor. It is composed of nine states, but just a small proportion of its total land is considered good for farming. Its main crops are cotton, sugarcane, and cocoa.

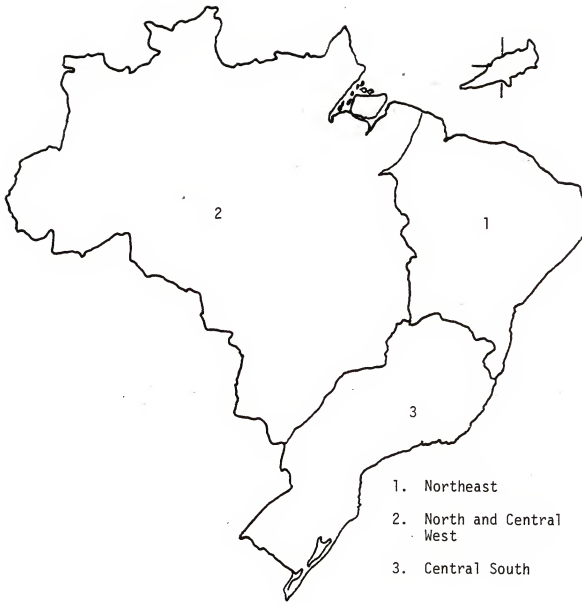

Figure 1. The regions of Brazil

The North and Central West regions, where the Amazon basin is located, cover more than half of the country. These regions have a low population, little industry and a primitive agriculture. Their ecologies are largely unknown. The regions remain a potential resource for Brazilian development. Main resources are minerals (iron, manganese, gold), water, timber, fish and wild animals.

Brazilian agricultural output has grown at an average rate of 4.7 per cent in the last four decades, which is a pace faster than that of the growth in population. However, acute inequalities in growth among crops and regions seem to remain. The South has specialized in the production of high pay-off export crops while the Northeast has concentrated in low pay-off food crops (Graham and Barros, 1980:1). The cumulative effect of this regional bias has been to enlarge inequalities through time. Also, some evidence indicates that growth in agricultural output has been due mainly to increase in the area of land cultivated and not to increase in yields (Graham and Barros, 1980:1). Some reasons why this pattern of development arose is presented in the next section about the historical development of Brazil and some of its regions.

Historical Background

Brazil was discovered by Portuguese navigators in 1500. This discovery was a by-product of the expansion of mercantilism, which caused a revolution in maritime navigation. Brazilian history is strongly tied to the economic history of Europe and the colonial period

(1500-1822) can be described based on trends in European economic activity.

Initially, it was necessary to occupy the new territory to defend it against threat of external rapine which came from France, Holland and England. Because of a lack of resources to be used for defensive purposes and a previous unsuccessful experience with sugar production in Africa, Portugal entered a joint venture with the Dutch to produce sugar in Brazil to supply Europe. This activity was profitable to both partners, and it fostered the development of a colony. Later this venture was discontinued because of market and political conditions (Furtado, 1967:24-31).

After sugar production subsided, gold and diamond mining became an important activity. Later coffee production was introduced. During this period Portugal and England were allied. During the colonial period the pattern of agricultural production was that of a main crop oriented to foreign markets, such as sugarcane, coffee, or cotton. This export production was supported by a subsistence agriculture to provide food for labor. The natives, slaves and expatriated people, without right to property, grew the crops necessary to feed themselves.

These two phenomena, export orientation and subsistence agriculture are fundamental to understanding the duality in Brazilian agriculture (Prado, 1969:13). The shifting of agricultural activities from sugarcane production in the Northeastern coastal zone to coffee

and other crops in the fertile Southern lands led to another kind of duality, i.e. a duality between regions.

The Northeast was the first region to be colonized in Brazil, and during the first two colonial centuries it was the richest region. Sugar production had several booms and busts, the golden epoch was from 1580 to 1650. However, under heavy Caribbean competition and a declining demand, the Northeastern economy began to decline.

In the 18th century the discovery of gold in the Southeast shifted the underemployed population from the Northeast and started the process of populating the Southeast. This new economic activity competed with the Northeastern region for resources such as slaves and working animals and the Northeast increasingly lost economic importance. The Court also transferred from the Northeast to the Southeast, with all the consequent political impact. Later, coffee production became profitable in the Southeast and a golden period, based on coffee exports, was begun.

With a greater knowledge of commerce, a highly skilled labor force (imported from Europe), and consciousness of their political power, the coffee producers were better prepared to face market and political crises than were the Northeastern sugar producers a century earlier. Profits from coffee exports were used to initiate industrial activities in Brazil (Furtado, 1967:177-185) and led to an interaction of industrial and political power and dynamism in agriculture in Southeastern Brazil.

The Northeast remained as a declining sugar-producing region. The Southeast later entered sugar production which made matters even more critical for the Northeast. A similar story can be told for the cotton era.

With regard to policy, Brazil remained a fundamentally agrarian country until 1930. And, even though there was a change toward industrialization, income from that sector did not supersede that from agriculture until 1956. The industrialization program was based upon substitution of imports and a new role was fostered for the agricultural sector. Aside from its role in providing a means to buy capital goods, it was also to provide, through its food subsector, cheap food to foster accumulation in the industrial sector (Oliveira, 1972). Food indirectly represents a large share of the cost in the industrial sector. This scheme was conceived at the federal level and policies were formulated to implement it.

Since the period of interest for this analysis is basically the post World War II period, indeed after 1950, a review of some policy issues during this period is important. The main areas for agricultural policies, from 1950 to 1966, were (Smith, 1969:213-14):

a) marketing facilities, to improve price incentives to farmers and expand production,

b) use of modern inputs, through exchange rate subsidies, tax exemptions and subsidized credit,

c) credit for agriculture, through official banks at negative interest

rates, and

d) minimum price programs.

From 1966 to 1980, in additon to the policies listed above, the government decided to reinforce the process of agricultural modernization by (Graham and Barros, 1980:5):

e) using a more aggressive and export oriented foreign trade policy (emphasizing processed or manufactured agricultural exports),

f) rapidly increasing rural credit,

g) expanding agricultural extension services, and

h) promoting the domestic production of key agricultural inputs (such as tractors, fertilizers, insecticides, and herbicides).

Some profit gains and reduced risks have been achieved through policies to foster increased production and productivity (areas a) to d)). These gains were made without a noticeable change in final prices (Smith, 1969:214). However, these market oriented policies have been overrated and there are serious limitations in their coordination with policies in other areas (Smith, 1969:214). According to Hapgood (1965), policy makers have given excessive attention to market aspects and have overlooked structural aspects such as education, research and land tenure.

In the late sixties and seventies there was a shift toward structural factors (policy areas e) to h)). Another indication of this shift was the reform of the Brazilian system of agricultural research (Pastore and Alves, 1975). Nevertheless, according to Graham and Barros (1980:5-6), the expansion of extension was a poor use of resources

since it assumed an existing stock of knowledge which did not exist and the results had a low pay-off.

The objectives of policies in those areas were twofold, to increase the efficiency of the agricultural sector as a whole and to attenuate inequalities among regions. The strongest evidence of this last aspect was the creation of a large development bank and a development agency (Banco do Nordeste do Brasil, BNB, and Superintendencia do Desenvolvimento economico do Nordeste, SUDENE), in the early fifties, to sponsor growth of the Northeast region.

Chaloult (1978) has shown that over the period 1960-1977 the role of the federal government has not always bean clear cut. This happens, he argues, due to the conflicting roles the state has to play in representing the interests of its strongest political base, the South; its own interests, since it is extremely active in the South; and finally, as legitimizing and attenuating existing conflicts in the society.

Problem Setting and Objectives of the Study

It is well known that in a developing nation the agricultural sector must play a crucial role. It should provide, through exports, revenue to buy capital goods and adequate production to assure cheap food for the urban sector in order to support industrial accumulation. With a large foreign debt and high inflation, Brazil has to rely heavily on the primary sector to export unfinished and semifinished goods and to increase domestic supply. To fulfill this function the

agricultural sector productivity must increase. An understanding of the roles of such things as quantities and qualities of inputs, marketing conditions, and institutional aspects in fostering productivity growth are essential for policy making.

Of major importance for this study are the main productivity aspects of Brazilian agriculture, i.e. the dynamism of Brazilian agricultural growth and inequalities among regions. Based on this the objectives of the study were to analyze two aspects of efficiency in Brazilian agriculture, namely to study:

i) growth of productivity over time in agriculture as a whole and

ii) regional disparities by comparing growth in productivity, factor use and patterns of input substitution in the South and Northeast, the main regions of the country.

An attempt was made to quantify the effect of rural credit, international trade, and traditional and modern inputs on agricultural productivity. It is hoped that a more complete understanding of the effects of policy action on productivity will suggest ways of improving agricultural policy interventions.

Plan of Dissertation

In Chapter II a review of literature in total factor productivity (TFP) and studies focusing on aspects of duality theory related to this work are discussed. The two models used in this work are specified and their data requirements are described.

In Chapter III the behaviors of inputs and outputs in agriculture are presented for the whole sector. Also some data that can be used to qualify the results, such as research, wages, credit and exports, are discussed.

Chapters IV and V present empirical results from two models. National growth in TFP, elasticities of value added with respect to the primary inputs and price of the intermediate inputs, elasticities of the derived demand for the intermediate inputs, and shadow prices of the primary inputs are estimated and discussed in Chapter IV. Also, an attempt is made to explain the growth in TFP and an intercountry comparison of results from similar studies is presented. In Chapter V the results on regional productivities and patterns of input use and substitution are treated. A qualitative analysis of the reasons behind the interregional differences is also presented.

Finally, Chapter VI summarizes the main findings. Implications for policy are suggested and study limitations are discussed.

Notes

1. Alagoas, Bahia, Ceara, Maranhao, Paraiba, Pernambuco, Piaui, R. G. do Norte, and Sergipe are the states in the Northeast region. Espirito Santo, Minas Gerais, Parana, R. G. do Sul, Santa Catarina and Sao Paulo are the ones in the South.

CHAPTER II

CONCEPTUAL FRAMEWORK

In the late fifties and sixties there was a steady supply of papers on productivity measures, a survey of these studies can be found in Nadiri (1970). In general, these studies were based on indices of partial or total productivity in which an index of inputs is compared to an index of outputs. If in the input index, one factor of production is used, the derived measure is called a partial productivity (PP) index. If all the inputs are used the measure is called a total factor productivity (TFP) index. Algebraically,

$$PP_j = \sum_i w_i Y_i / \theta_j X_j \qquad (1)$$

$$TFP = \sum_i w_i Y_i / \sum_i \theta_i X_i \qquad (2)$$

where Y's are outputs, X's are inputs, and w's and θ's are weights.

Recent studies in the theory of production have demonstrated that behind each index of productivity there is a corresponding exact production function (Diewert, 1976); e.g., a Paasch index is exact for a linear production function and the Tornqvist index is exact for the homogeneous translog production function. Therefore, one should not construct indices of productivity without consideration of the underlying production function.

Bearing this relationship in mind, most recent studies have presented indices of productivity based on the corresponding production

function as in the works of Hertford (1971), Gollop and Jorgenson (1975), and Christensen, Cummings & Jorgenson (1975). Basically these studies use two different ways to handle the measurement problem. One consists of postulating a production function and deriving consistent output and input indices. The other estimates a production function and uses weights derived from it to calculate growth in productivity (e.g., assuming a Cobb-Douglas with capital and labor as inputs the growth in TFP is given by

$$dTFP/TFP = dY/Y - \sum_{i=1}^{2} a_i \, dX_i/X_i$$

where Y is output, X_1 and X_2 are capital and labor, respectively, and the a's are the estimated factor intensities in the production function). Both of these methods are theorical improvements over the older procedure of blindly calculating indices.

Duality

Due to a lack of data and the largely unobservable character of the production function (Silberberg, 1978:313-14), work on measuring productivity became unpopular among analysts. However, with the development of duality theory in the seventies (for examples, Diewert, 1971; Lau & Yotopolus, 1971; Lau, 1978; and McFadden, 1978),* there has been a renewed interest in productivity measurement.

Basically, given a production function, a dual relation exists, which makes it possible to derive a conjugate profit or cost function from which one can trace properties of the primal relation. Obviously what is primal or dual can be interchanged. The utility of

this device is that all quantities of commodities and variable inputs are replaced by their price and vice versa. This operation can be of great value in empirical measurement because of both data and econometric requirements.

Legendre's Transform

All the mathematical background necessary for duality theory can be summarized in a very powerful yet simple device, Legendre's transform. A short outline of this device is presented here (see also Rockafellar (1970:251-60) and Lau (1978:142-47) for greater details).* Consider a function of k variables, say V_i, and n parameters, P_j,

$$f = f(V_1,\ldots, V_k; P_1,\ldots, P_n)$$

one can define new variables, T 's, by the derivative transformation

$$T_i = \partial f/\partial V_i,\ i = 1,\ldots,k$$

which are called the Legendre's transform.

Assuming f to be locally strongly concave in the V 's this implies that the transformation is nonsingular; i.e., the Jacobian is nonvanishing, and hence invertible. Thus one can solve the system to have

$$V_i = h_i(T_1,\ldots,T_k; P_1,\ldots, P_n).$$

A new function g can be defined as follows

$$g(T_1,\ldots,T_k; P_1,\ldots,P_n) = \sum_{i=1}^{k} h_i(T,P)\, T - f(h_1(T,P),\ldots,h_k(T,P),P)$$

which is the Legendre's dual transformation of the primal function f.

Several interesting relationships emerge between these two functions. First one should notice that

$$\partial g/\partial T_i = \sum_j (\partial h_j(T,P)/\partial T_i)\, T_j + h_i - \sum_j \partial f/\partial V_j \cdot \partial h_j/\partial T_i = h_i,\ i = 1,\ldots,k,$$

since

$$\partial f/\partial V_j = T_j,$$

therefore

$$\partial g/\partial T_i = h_i(T,P) = V_i$$

which is the inverse Legendre's transformation.

Another useful relation is the one produced by the derivative of g with respect to P ; i.e.,

$$\partial g/\partial P_i = \sum_j (\partial h_j/\partial P_i)\, T_j - \sum_j \partial f/\partial V_j \cdot \partial h_j/\partial P_i - \partial f/\partial P = -\partial f/\partial P_i$$

If one denotes by M a vector of intermediate or variable inputs and by X a vector of primary or fixed inputs a production function F(M, X) can be considered as f, the profit function G(q,X), where q is the price vector of M, as -g; M and X as V and P respectively. With these definitions, T would be the marginal products of M; i.e.,

$$T = \partial F/\partial M$$

but under profit maximization, and if q is normalized,

$$T = \partial F/\partial M = q,$$

which implies that

$$F = G - q' \cdot \partial G/\partial q$$

and as before

$$g = \sum_{i=1}^{k} q_i m_i(q,X) - F\,(m_1(q,X),\ldots,m_k(q,X),\ M) = -G.$$

Based on these relations one can establish and justify the important concepts in duality theory, such as

$$\partial g/\partial q_i = m_i, \text{ or } \partial G/\partial q = -M \qquad (3)$$

which is Shephard's lemma. Also one can see that

$$\partial g/\partial X = - \partial F/\partial X$$

which implies that

$$\partial G/\partial X = \partial F/\partial X; \text{ i.e.,}$$

the derivatives with respect to the fixed inputs are invariant under the dual transformation.

Another Interpretation of TFP

A common definiton of TFP is that of a ratio of an index of outputs to an index of inputs. Some elaboration, however, can refine this interpretation. If value added is used to represent aggregate output, TFP may be measured as

$$TFP = V.A./ \Sigma w_i X_i$$

where V.A. stands for value added and $\Sigma w_i X_i$ is a weighted combination of primary inputs. If one recalls that value added is the income accruing to the primary inputs plus a residual, the ratio above may be written as

$$\Sigma \theta_i X_i / \Sigma w_i X_i + S/ \Sigma w_i X_i$$

where $\Sigma \theta_i X_i$ represents a monetary value of the primary inputs, the w's represent shadow prices, and S is the amount of the residual. If the weights forming the combination of inputs are market prices (i.e., $\theta_i = w_i$, $\forall i$), or shadow prices equal to prices under the assumption of

perfect competion, the first term in the expression above is identically equal to one. The second term is a measure of the "free energy" ratio in the system.

Now let

$$\Sigma\, \theta_i X_i = y$$

$$\Sigma\, w_i X_i = y_2, \text{ and}$$

$$\Sigma\, \theta_i X_i + S = T$$

then,

$$dTFP/dt = R_{TFP} = (y_1/T).\ R_{y1} + (S/T)\ R_s - R_{y2}$$

where R stands for rate of growth and t denotes time. In order to have $R_{TFP} > 0$ the condition

$$y_1 R_{y1} + S R_s - T R_{y2} > 0$$

must be fulfilled. Under the assumption $y_1 = y_2 = y$ the condition above can be simplified to

$$S (R_s - R_y) > 0.$$

If S is positive this condition becomes

$$R_s > R_y$$

or, the residual should grow faster than the monetary value of the primary inputs. Therefore one should require an exponential growth in the net rate of profit ($S/\Sigma\, w_i X_i$) to have the system developing, and this is equivalent, under the assumptions above, to a positive growth of TFP.

Griliches (1969:331-32) postulates that if inputs are correctly measured, including variation in quality, the residual left from the difference between growth in output and inputs is nil. This

procedure has relevance in explaining growth in TFP. However, it seems futile if the main goal is to quantify growth in the system. This study rather adopts the definition given by Kendrick (1977:18), which disregards changes in quality since quality improvement in inputs is a major source of productivity growth and represents part of what one is attempting to measure.

The Value-Added Approach

A value-added approach was suggested by Bruno (1978) and was taken as a restricted or mixed profit function. Defining

$$Y = Y(X, M)$$

as a production function dependent on a vector of primary inputs, X, and a vector of intermediate inputs, M. The value-added function is defined as

$$G(X, \pi, P) = \max_{Y,M} [Y - P'M \quad Y \leq y(X, M)] = \pi Y(X, P, \pi) - P'\bar{M}(X, P, \pi) \qquad (4)$$

where π is output price, P is the price vector of intermediate inputs and $\hat{Y}$, $\hat{M}$ are optimal quantities from the maximization of profits with respect to the intermediate input. This function is concave in X and convex in the prices of M. It should be observed that value added, X, π and P are the only variables necessary for estimation.

If the nominal value-added function above is deflated by the output price, π, one has what is called the single deflated value-added function, SVA for short, or

$$g = G/\pi$$

The following relations hold for this function

$$\partial g/\partial X = g_X = \partial Y/\partial X = Y_X \tag{5}$$

$$\partial g/\partial p = g_p = -M \tag{6}$$

where $p = P/\pi$. Also, under profit maximization and perfect competition,

$$\partial Y/\partial M = Y_M = p \tag{7}$$

If the original production function is defined as

$$Y = Y(X, M, t)$$

where t is scalar shifter for technical progress, one can measure TFP directly from SVA, keeping in mind that TFP is defined as $\partial Y/\partial t$, now defined as

$$g = g(X, p, t).$$

Totally differentiating g with respect to t one gets

$$dg/dt = \partial g/\partial t + g'_X \, dX/dt + g'_p \, dp/dt, \text{ or}$$

$$g = \partial g/\partial t = dg/dt - g'_X \, dX/dt - g'_p \, dp/dt \tag{8}$$

The way g is defined implies

$dg/dt = dY/dt - p' \, dM/dt - M \, dp/dt$. Making this substitution into (8) and using the relations (5), (6) and (7) one has

$$g_t = dY/dt - Y'_M \, dM/dt + g'_p \, dp/dt - g'_X \, dX/dt - g'_p \, dp/dt$$

$$= dY/dt - Y'_m \, dM/dt - Y_X \, dX/dt = Y_t$$

Thus the way to measure TFP is equivalent using either a value-added or a production function.

Empirically TFP is approximated by[1]

$$q = dg/dt - g'_X \, dX/dt \tag{9}$$

From (8) one can see that this definition is biased because it does not

take into account the variation in the prices of the intermediate inputs, which is given by $g_p'\, dp/dt$.

Since the value-added function depends on the prices of the intermediate inputs as well as the price of the output, double deflating could remove this bias. If one deflates value added in such a way that the prices are normalized in a base period so that all are equal to one, the result is

$$F = Y - M' e$$

where e is a vector of 1's. This function is called double deflated value-added (DVA). It can be written as

$$F = g + g_p' (e - p).$$

The partial derivatives of F with respect to p and X are given by

$$\partial F/\partial p = - Y_{MM}^{-1} (e - p), \quad \text{where } Y_{MM} = \partial^2 Y/\partial M\, \partial M, \text{ and}$$

$$\partial F/\partial X = F_X = Y_X - Y_{MX} F_p, \quad \text{where } Y_X = \partial Y/\partial X,\ Y_{MX} = \partial^2 Y/\partial M\, \partial X.$$

Again if the production function, Y, includes a time shifter, t, the change in TFP can be estimated using the expression

$$\hat{q} = dF/F - (g_X'/g)\, dX$$

where g'/g are the competitive income shares of the primary inputs. The actual change in TFP (corrected for output scale) is given by

$$q^* = (Y/F)\,(Y_t/Y)\, dt = (Y_t/F)\, dt.$$

Therefore, in order to know if q is an unbiased measure, it is necessary to evaluate $\hat{q} - q^*$ to see if this quantity vanishes. Totally differentiating F with respect to t, multiplying the result by $(1/F)\, dt$ and using the definitions of $\hat{q}$ and q^*, one obtains[2]

$$\hat{q} - q^* = F'_p / F \, (dp - X_{Mt}dt + Z_{Mx}dX), \text{ where}$$

$$Z_{Mx} = (g'_x \; Y_{MM} / g) - Y_{Mx}$$

The difference between $\hat{q}$ and q*will vanish either if $F_p = 0$ or if the term in parentheses is zero. The first hypothesis; i.e., $F_p = 0$, requires either $Y_{MM} \to 0$, which means that the intermediate inputs are used in fixed proportions, or e = p, which can occur if F was obtained from a Divisia index of inputs and gross output or if the relative prices are constant. The second alternative is extremely unlikely and does not deserve discussion but it is interesting to notice that functional separability of the form

$$Y (X, M) = H ((h (X) + \sum_{mkEk} \alpha_k M_k)$$

is no longer sufficient to eliminate the bias.

The Dual Cost Function Approach

A second approach to duality was described by Diewert (1978). He has shown that from the unit value-added cost function

$$C (\pi, p) = \underset{X}{\text{Min}} \, [p'X : V (\pi, X) \geq 1, X \geq 0] \text{ if } \pi \geq 0, \; \pi \varepsilon Z$$

$$= \infty \text{ if } \pi \varepsilon Z$$

(where V is value added, π is output price, p is the input price vector and X is a vector of primary inputs) satisfying the conditions:

i. C (π, p) is a postive extended real valued function defined for $\pi > 0$, and $C(\pi, p) = \infty$ for $\pi \varepsilon Z$, where Z = $[\pi : V (\pi, 1) = 0, \pi \geq 0]$.

ii. C is continuous from above in (π, p).

iii. C is quasi-concave in (π, p).

iv. C is homogeneous of degree -1 in π for fixed p.

v. C is homogeneous of degree 1 in p for fixed π.

vi. C is nondecreasing in p for fixed π.

From this cost function the value-added production function can be obtained in the following way:

$$V(\pi, X) = \underset{\lambda}{\text{Max}} [\lambda: C(\pi, p)\lambda \leq p'X \vee p \geq 0 \mid p'X = 1]$$
$$= \underset{\lambda}{\text{Max}} [\lambda: \lambda \leq p'X/C(\pi, p) \vee p \geq 0 \mid p'X = 1]$$
$$= \underset{p}{\text{Min}} [1/C(\pi, p) \mid p \geq 0, p'X = 1]$$
$$= \underset{p}{\text{Min}} [1/C(\pi, p) \mid p \geq 0, p'X \leq 1]$$

Therefore one can be sure that a cost function satisfying certain conditions has a corresponding dual value-added production function which can be derived from it. The empirical estimation of this production function may be intractable, or excessively cumbersome. What one normally does is to find a way to get the information needed from the cost function which can be estimated (e.g., how to calculate TFP from the cost function will be shown later). The existence of a dual value-added production function places one on sound theorical grounds for using a cost function.

The Legendre's transform allows one to generate a set of demand functions for the inputs from the unit value-added cost function; i.e.,

$$X_i(V, \pi, p) = V \partial C(\pi, p) / \partial p_i$$

and econometric estimation can be performed in several ways. The only requirement is that the cost function satisfy the conditions enunciated

above. The extension to include intermediate inputs in this function is straightforward (Denny & May, 1978).

The Mixed Profit Function Model Specification

In order to get the coefficients to calculate TFP, it is necessary to postulate an empirical form for the value-added function described in equation (4). The transcendental logarithmic function was chosen because it can be interpreted as a second order Taylor's series approximation, in transformed variables, to a monotonic transformation of the true underlying function.

Consider that the true function is given by $f(x_1,\ldots,x_n)$ and write it as

$$f(x_1,\ldots,x_n) = \bar{f}(h_1(x_1),\ldots,h_n(x_n))$$

where the h's are any twice differentiable transformations of the original variables. Composing f with a twice differentiable monotonic transformation, say g, it follows that

$$g \circ f(x_1,\ldots,x_n) = g \circ \bar{f}(h_1(x_1),\ldots,h_n(x_n))$$

Of course one can approximate this composition by a Taylor's series expansion around $(h_1(\bar{x}_1),\ldots,h_n(\bar{x}_n))$, where this n-tuple belongs to the nonnegative orthant, say Ω_+^n, i.e.

$$g \circ f(X) = g \circ \bar{f}(h(\bar{X})) + V_{\bar{X}}' [h(X) - h(\bar{X})] + 1/2 [h(X) - h(\bar{X})]' V_{\bar{X}}^2 [h(X) - h(\bar{X})] + \ldots$$

where $h = h_1,\ldots,h_n$, $X = x_1,\ldots,x_n$, $V_{\bar{X}}' = [\partial g \circ \bar{f}/\partial \bar{x}_1,\ldots,\partial g \circ \bar{f}/\partial \bar{x}_n]$, and $V_{\bar{X}}^2$ is the Hessian of $g \circ \bar{f}$ evaluated at $X = \bar{X}$.

Expressing differently one has

$$g \circ f(X) = \bar{\alpha}_0 + \sum_i \bar{\alpha}_i [h_i(x_i) - h_i(\bar{x}_i)] + 1/2 \sum_i \sum_j \bar{\beta}_{ij} [h_i(x_i) - h_i(\bar{x}_i)] [h_j(x_j) - h_j(\bar{x}_j)] + \ldots$$

eliminating terms of order higher than two, rearranging and renaming the terms left

$$g \circ f = \alpha_0 + \sum \alpha_i h_i(x_i) + 1/2 \sum_i \sum_j \beta_{ij} h_i(x_i) h_j(x_j) + \ldots$$

with $\beta_{ij} = \beta_{ji} \forall i,j$, where

$$\alpha_0 = \bar{\alpha}_0 - \sum_i \bar{\alpha}_i h_i(\bar{x}_i) + 1/2 \sum_i \sum_j \bar{\beta}_{ij} h_i(\bar{x}_i) h_j(\bar{x}_j)$$

$$\alpha_i = \bar{\alpha}_i - \sum \beta_{ij} h_j(\bar{x}_j), \beta_{ij} = \beta_{ji}, \forall i,j$$

Several functional forms can be written in this way. Examples of them are the Quadratic ($h_i(x_i) = x$, $g(f) = f$); Generalized Leontief ($h_i(x_i) = x_i^{1/2}$, $g(f) = f$); Generalized Quadratic Mean of Order ρ ($h_i(x_i) = x_i^{\rho/2}$, $g(f) = f^{1/\rho}$); and the Translog ($h_i(x_i) = \ln x_i$, $g(f) = \ln f$).

This kind of approximation is stronger than a second order approximation in Diewert's sense (Diewert, 1973) and it has the important property of being a numerical approximation in any prescribed neighborhood of $\bar{X}$, the error of approximation being bound by the size of higher order terms.

Besides this property the translog has some other nice properties (Berndt and Christensen, 1973:87) and it has performed satisfactorily in a similar study by Ahmad (1982).

Description of the Analysis

The translog approximation of a value-added function was estimated by standard OLS techniques to obtain the coefficients

necessary to calculate g_X and g_p in the expression

$$q = dg/dt - g'_X\, dX - g'_p\, dp.$$

The weights g_X, g_p are the derivatives of g with respect to the primary inputs and the price of the intermediate inputs, using the estimated coefficients. The element dg/dt was obtained by regressing the logarithm of g on time and taking its derivative with respect to time; dX and dp were obtained in a similar way.

In addition to the growth in TFP the elasticities of value added with respect to the primary inputs and the prices of the intermediate inputs were calculated. Using equation (6) the derived demand for intermediate inputs was calculated along with the corresponding elasticities. Shadow prices of the primary inputs were obtained through equation (5).

Finally, estimated values of q over time were regressed on selected "policy variables," agricultural credit and exports, in an attempt to better understand the causes of growth in TFP. A similar approach was used by Chenery, Shishido and Watanabe (1962). They regressed partial labor productivity (Y/N) on the fraction of production exported (E/Y) and the fraction of total supply imported (M/M+Y). They estimated that the changes in export and import ratios explained about 80 per cent of the variance in labor productivity. In Chapter III the reasons why international trade and money credit influence TFP will be discussed. However, it is important to stress that this regression does not necessarily show a causal relationship between productivity and those variables. This relationship may,

however, provide some exploratory information toward a more complete understanding of the causes of growth in TFP.

Data Set

Time series data from 1950 to 1976 were available on value added by the agricultural sector (Conjuntura Economica, several issues). Unfortunately, the Brazilian accounts report only nominal value added and prices of all intermediate inputs through time are not available, this fact made it impossible to use DVA in the analysis. Data about tractors and their value, given in terms of horsepower, were available from IPEA (Instituto de Pesquisas Economicas e Sociais, personal communication). The value of buildings to 1969 was estimated by Langoni (1974) and an exponential extrapolation was performed to complete the series. The value of working animals is reported by Anuario Estatistico (several issues). These last three categories were summed and defined as fixed capital in agriculture. The quantity of land in temporary and permanent crops was also reported by Anuario Estatistico (several issues) and their sum was defined as land used in agriculture. Total labor in agriculture was available only for the census years. An exponential interpolation was used to estimate the missing values for this series. Fertilizers was the only intermediate input used in the analysis since it was the only one for which time series prices were available (IPEA, personal communication). Indices of output and machinery prices were available from Conjuntura Economica (several issues).

Data on exports were available from the annual report of the Bank of Brazil (Relatorio Anual do Banco do Brasil, several issues) and from the works of Doellinger et al. (1973) and Silva, Fonseca and Martin (1979). Data on agricultural credit came from the work of Tendler (1969) and from official statistics (Series Estatisticas Retrospectivas, 1977). A variable measuring minimum price policies was sought to include in the exploratory relationship to explain variation in TFP growth. However, data about minimum prices were available only for a few commodities.

Disaggregated time series data for the two regions, South and Northeast, were rather inadequate but the agricultural census of 1960, 1970 and 1975 did report the required data. Initially, a profit function analysis, like the one used for the agricultural sector of the country, was performed in order to see the consistency of the two sets of results. Lack of price data in 1960 precluded a deeper investigation.

The Cost Function Model for Interregional Comparisons

The cost function approach described in the review of literature was approximated with a translog function for reasons cited previously and to give uniformity to the study. The version chosen was a mix of the function applied by Denny and May (1978:56) and the one used by Ray (1982:491); i.e., a time trend was added to the former to reflect Hicks-neutral technical change. The function estimated was

$$\ln C = \alpha + \sum_i \alpha_i \ln p_i + 1/2 \sum_i \sum_j \beta_{ij} \ln p_i \ln p_j + \sum \beta_{iv} \ln p_i \ln V + 1/2 (\ln V)^2 + \theta t,$$

where p_k represents the price of the k-th input, V is value added, C is total cost of the inputs and t represents a time shifter.

The Legendre's transform justifies the operation of deriving demand, or share equations, from this function; i.e.,

$$\alpha_i = \beta_{ii} + \sum_j \beta_{ij} \ln p_j + \beta_{iv} V, \quad i,j = 1,\ldots,n$$

where $\alpha_i = p_i X_i / C$ is the share in total cost of the i-th input.

From the cost or share equations several important economic relations can be derived. McFadden (1978:78-80), for the general case, and Binswanger (1974:378-80), for the translog, have shown that the own-price elasticity of the input i is given by

$$N_{ii} = \beta_{ii} / \alpha_i + \alpha_i - 1 \qquad (10)$$

the cross-price elasticity is

$$N_{ij} = \beta_{ij} / \alpha_i + \alpha_j \qquad (11)$$

and the elasticity of substitution between inputs i and j is given by

$$\vartheta_{ij} = \beta_{ij} / \alpha_i \alpha_j + 1. \qquad (12)$$

These concepts are useful in assessing factor usage and patterns of substitution between inputs in the two regions.

When more than two inputs are present in the analysis several definitions for the elasticity of substitution can be suggested (McFadden, 1978:79-80). And each definition has a different economic interpretation. The one being used here is the Allen-Uzawa elasticity of substitution which provides information on the cross and own demand

elasticities for inputs but does not provide direct information on the behavior of the relative shares.

Description of the Regional Analysis

In addition to the analysis described above changes in TFP for the two regions were measured. Although a cost function was used, an equivalence with the production, or value-added function can be exploited to obtain a measure of total productivity. The procedure can be described in the following way. Given a production function,

$$G(Y) = F(X, t),$$

where G may be the identity function, Y is output, X is a vector of inputs and t is a time trend. The notion of total productivity growth is simply

$$E_{Ft} = \partial \ln F(X, t) / \partial t$$

which is empirically approximated by $\dot{Y}/Y - \dot{X}/X$, where dots mean time derivatives. If the dual cost function is given by

$$C = C(Y, p_1, \ldots, p_n, t)$$

where p_k is the price of the k-th input, the elasticity of cost with respect to output is defined as

$$E_{cy} = \partial \ln C / \partial \ln Y$$

and the associate dual rate of returns to scale is

$$E_{cy}^{-1} = 1 / E_{cy}.$$

Finally, one can define the dual rate of total cost diminution

$$E_{ct} = - \partial \ln C / \partial t$$

and Ohta (1974) has shown that in general

$$E_{Ft} = E_{cy}^{-1} E_{ct}.$$

Therefore, total factor productivity can be measured either from the original production function or from its dual cost function. Moreover, the measure derived is unbiased as can be seen from the equation above (see the comment by E. Berndt to the article by Gollop and Jorgenson, 1975).

There are three ways to estimate the cost function. One is to estimate it directly which may lead to problems of multicollinearity and simultaneity. Another is to estimate only the share equations and from them to derive the parameters of the cost function. In this way one has more degrees of freedom in the analysis; however, with the particular cost function being used here at least the coefficient of the time trend is lost in this operation. The third method is to estimate the cost and the share equations simultaneously, which leads to more efficient estimates (Ray, 1982:492). In this study the third approach was used.

Pooled data are sensitive to several econometric problems. If efficiency and scale differences exist among the observational units, the econometric specification should allow for them. As a consequence, a time trend to take care of efficiency differences and a variable representing value added, to isolate scale effects, were included in specifying the equation. It is possible that the errors in the equations are not independent within each of the cross-sections. Based

on this Zellner's seemingly unrelated regression technique was used. Moreover, it is possible, with the pooling of all cross-sections, that there is error dependence over time. The small size of the data set precluded the application of a suitable technique for this problem.

Finally, given the requirements that the shares should sum to one and that the cost function should be homogeneous in prices, the following restrictions were imposed on the model

$$\sum_i \beta_i = 1$$
$$\sum_i \sum_j \beta_{ij} = 0$$
$$\sum_i \beta_{iv} = 0.$$

Regional Data Set

Data from the agricultural census were used for estimation. The data set follows closely the definitions given by Binswanger (1974:385-86). Expenditures for land, labor and capital were calculated in the following way: a) expenditures for land were estimated as 4 per cent of total land value (total land value was calculated as the total hectares of land in permanent, temporary, and pasture crops times the value of an hectare of rented land) b) expenditures for labor were simply the total wage bill reported by the agricultural censuses, and c) expenditures for capital were defined as the amount due to depreciation, interest and service charges, plus operational expenditures (expenditures for fuels). Only machinery and financial assets were considered as capital.

The prices of the inputs were obtained by dividing total expenditure for the input by the number of items, which really gives the unitary expenditure for the input. Finally, expenditure shares were obtained by dividing the expenditures for the input by total expenditures.

Notes

1. The expression defining q is exactly equivalent to the measure of growth in TFP, using a Cobb-Douglas production function, discussed in Chapter II. It is important to realize that when this measure is applied it ignores the variation in the price of the intermediate inputs.
2. See Bruno (1978) for the details.

CHAPTER III

INPUT AND OUTPUT TRENDS AND FACTORS INFLUENCING TFP

Traditional Inputs

This chapter presents the trend in traditional inputs, capital, land and labor which were used in estimating growth rates of TFP. Growth rates of these items during the period 1950-1976, together with the growth of value added also show their behavior during the study period. Growth rate for some classes of commodities are shown to help describe the progress among the several subsectors of agriculture.

Capital was defined previously as the sum of the value of working animals, tractors, and buildings. Land was defined as total harvested area with permanent and temporary crops and labor as the total number of persons employed in agriculture. Capital had the fastest growth among the inputs (Table 1 and Figures 2-4). This growth in capital was primarily due to the increasing mechanization of Brazilian agriculture. The increase in land comes from the large and unexploited reserves of agricultural land. Growth in land per se was not an indication of growth in its productivity or in the productivity of other inputs. Finally, labor increased modestly throughout the whole period which is an indication that the agricultural sector managed to maintain or increase its labor efficiency and to release increasing proportions of its population for nonagricultural purposes.

Table 1. Growth rate of traditional inputs and value added in agriculture, 1950-1976

Item	Growth rate[a]
	%
Land	3.0
Labor	2.5
Capital	4.0
Value Added	3.1

a) Estimated by regressing the logarithm of the item on time.
Source: Tables A-1, A-2, A-3 and A-4.

Table 2. Amount of labor, land, and capital used in Brazilian agriculture, selected years

Year	Labor	Land	Capital
	(workers)	(hectares)	(tractors)
1950	10,996,834	17,775,000	8,372
1960	15,633,985	25,230,600	61,345
1970	17,582,089	33,984,000	165,870
1975	20,345,692	36,600,000	323,113

Source: Censo Agropecuario do Brasil (1950, 1960, 1970 and 1975).

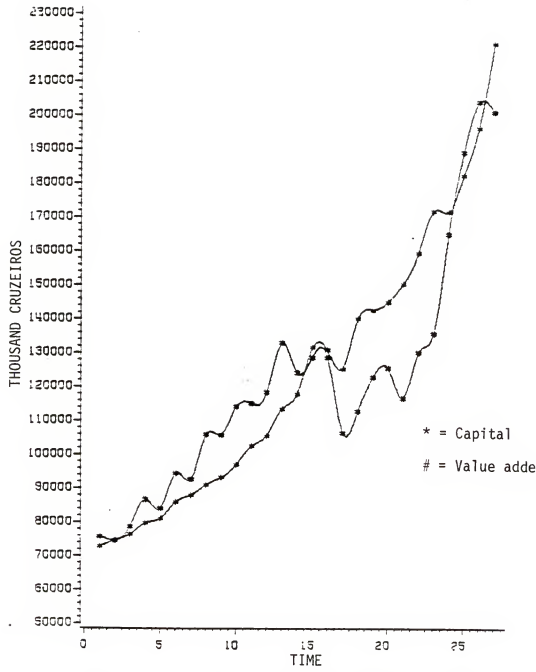

Figure 2. Trends of fixed capital and value added

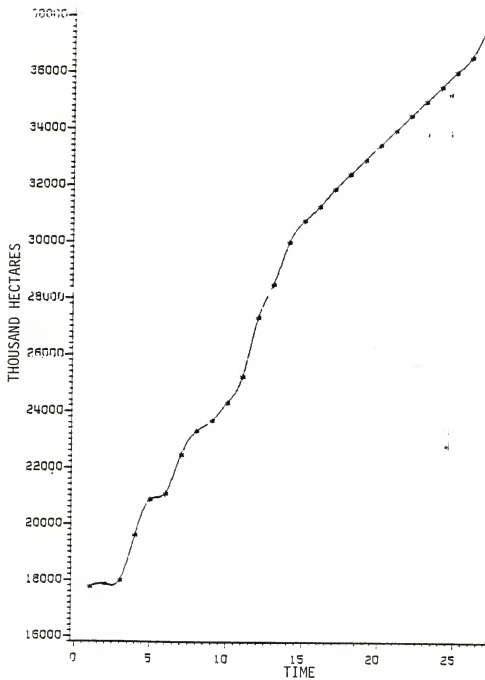

Figure 3. Trend in land

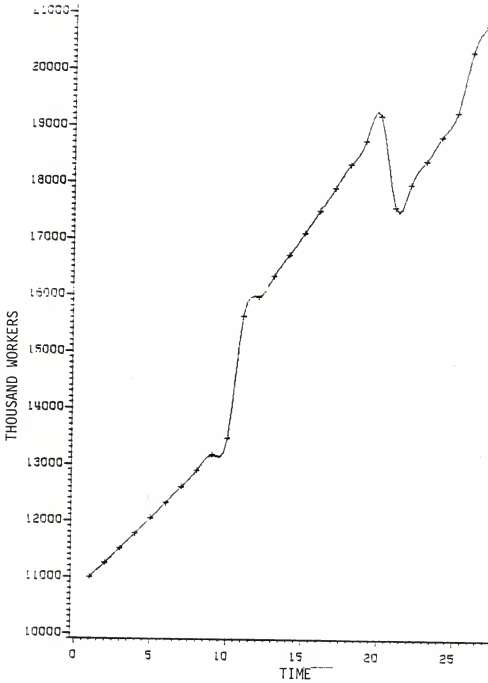

Figure 4. Trend in labor

Use of traditional inputs in census years is presented in Table 2. Labor experienced irregular growth, slowing down between 1960 and 1970. This fact should be an indication of growth in agricultural productivity, since a smaller percentage of the labor force represents, in general, a modernization of the sector. Land had a smooth trend, almost linear, showing the steady settlement of new land in Brazil. Finally, one can see that capital, represented by the number of tractors, increased dramatically in the fifties and approximately doubled in both the sixties and seventies. The general picture of growth in traditional inputs was favorable to modernization.

Modern Inputs

Modern inputs such as fertilizers, pesticides, and improved seeds play an important role in increasing productivity. Data on these inputs in Brazil have not generally been reported in time series form. The one major exception was data on fertilizer use (Table 3). Usage increased more than twenty times between 1950 and 1973. It increased rapidly in the late 1950's, had a lull in the early 1960's, and again grew rapidly beginning in 1967. This growth was primarily due to subsidized and duty free imports, a common pattern in Brazilian agricultural policy.[1] Duty free imports of fertilizers and pesticides existed during the period for which data were available for this study (Graham and Barros, 1980:8).

Data on the use of insecticides, fungicides and herbicides were available for part of the period. Table 4 shows that the

Table 3. Usage of N, P, and K in Brazil, 1950-1976

Year	Usage (1000 metric tons)
1950	89.0
1951	121.0
1952	173.0
1953	117.0
1954	123.0
1955	161.0
1956	165.0
1957	207.0
1958	256.0
1959	226.0
1960	299.0
1961	248.0
1962	237.0
1963	314.0
1964	255.0
1965	290.0
1966	281.0
1967	448.0
1968	603.0
1969	630.0
1970	999.0

Table 3. Continued

1971	1165.0
1972	1746.0
1973	1679.0
1974	1824.0
1975	1977.0
1976	2464.0

Source: Ruff and Missiaen (1975:47), Series Estatisticas Retrospectivas (1977:124).

production of chemical defensives increased modestly during the period 1967-1976 with an abrupt decrease in 1976. Ruff and Missiaen (1975:59) present an estimate of apparent consumption of defensives in Brazil for the years of 1967 an 1973. Their figures differ from the preceding table by the addition of imports (Table 5). According to their calculations the sum of the three items increased by 54.0 per cent between 1967 and 1973. They argue that the apparently stagnant growth in consumption of insecticides was due to the use of a more concentrated product.

Finally, data for the use of improved seeds in the South region are given in Table 6. Data for the whole country were unavailable. The South region is the richest in the country and the region where most of the research efforts are concentrated. Also, one should note that the larger share of croplands seeded with improved seeds goes to export crops. Domestic staple food crops, such as rice and beans, have an insignificant percentage of their area seeded with improved seeds. Cropland planted with improved seeds has shown a dramatic increase for wheat, a commodity where astonishing improvements in yields have been attained with modern varieties.

The adoption of improved seeds has been encouraged since the mid-seventies, with the implementation of a national seed plan (Graham and Barros, 1980:18). However, this program would have little effect on this analysis because of its very recent vintage.

Table 4. Brazilian production of insecticides, fungicides and herbicides, 1967-1976

Year	Defensive		
	Insecticides	Fungicides (metric tons)	Herbicides
1967	7700.0	-	-
1968	6847.0	-	-
1969	11504.0	-	-
1970	13115.0	-	-
1971	13279.0	2939.0	-
1972	14005.0	4250.0	-
1973	15610.0	6300.0	450.0
1974	14454.0	7558.0	826.0
1975	15616.0	9245.0	1700.0
1976	7738.0	9328.0	1500.0

Source: Series Estatisticas Retrospectivas (1977:124).

Table 5. Use of defensives in Brazilian agriculture, 1967 and 1973

Year	Insecticides	Defensive Fungicides (metric tons)	Herbicides
1967	33514.0	5685.0	1451.0
1973	33844.0	32382.0	8381.0

Source: Ruff and Missiaen (1975:59).

Table 6. Percentages of selected crops seeded with improved seeds in the South of Brazil, 1967 and 1971

Crop	1967	1971
	%	%
Wheat	28.0	89.0
Cotton	69.0	77.0
Soybeans	69.0	66.0
Corn	19.0	22.0
Potatoes	12.0	20.0
Rice	5.0	12.0
Peanuts	4.0	7.0
Beans	-	3.0

Source: Ruff and Missiaen (1975:58).

Output

Value added exhibited a growth rate of 3.1 per cent from 1950 to 1976 (Table 1) which is approximately equal to the growth rate in population for that period. Graham and Barros (1980) have estimated the growth rates in quantities produced of several crops during the period 1960-1977. They classify crops into two groups: exports and food crops.

On the average, and with the exception of cotton, the production of export crops grew faster than that of food crops (Table 7). If one excludes the Northeast region, the growth rate in cotton production was 2.0 per cent rather than being negative. Cotton production has been neglected in the Northeast and little attention has been given to research. In contrast a sizeable research effort toward this crop has been initiated in Sao Paulo. Growth in food crops has declined except for corn. This pattern can be explained by the higher profitability of export crops which attract resources for these activities. This variation among crops has differential impacts on production for each agricultural subsector, and growth in output, or value added, is not uniform. An increasing dynamism in the production of goods destined to foreign markets is partially offset by a decline in the production of staple foods consumed by the domestic market.

Research, Exports, and Credit

Research, exports, and credit are factors that have a role in explaining changes in total factor productivity. These factors may be useful in fostering future gains in agricultural productivity. The

Table 7. Growth rate of selected export and food crops, 1960-1977

Export Crops	Growth Rates[a]
	%
Cotton	-1.1 (2.0)
Cocoa	3.4
Sugar	2.7
Soybeans	1.5
Food Crops	
Rice	-0.7
Beans	-1.4
Cassava	-0.5
Corn	0.9

a) Excluding Northeastern production.
Source: Graham and Barros (1980:10).

studies of Smith (1969) and Graham and Barros (1980), stress the point that research and extension have been largely neglected by governmental policies in Brazil. There were reasonable research and extension efforts in states like Minas Gerais and Sao Paulo due to actions of state governments (Smith, 1969:12). Both authors point out the lack of coordination between national and state governments in efforts to improve agricultural productivity.

Data about agricultural research and extension are sparse. However, Silva, Fonseca and Martin (1979) have compiled a number of scientific papers published on agriculture. The effect of this variable on productivity is hard to interpret because of a lack of information linking number of papers published and pratical applications. However, one would expect a positive correlation between the number of scientific papers published on agriculture and progress in this sector.

Evenson and Kislev (1975) present information which makes it possible to calculate ratios of scientific papers published in Brazil and a few selected countries as well as ratios of expenditures on research for the year 1967. Compared to the developed countries Brazil has done poorly (Table 8). Its expenditures on agricultural research amounted to only 1.2 per cent of the U.S. expenditures and its number of papers published to 2.0 percent. Compared to developing countries, Brazil's performance is improved but it is still below India and Israel. The comparison with Indonesia and Mexico shows that these two countries rank well below Brazilian efforts in agricultural research.

Table 8. Ratios of expenditure on research and number of scientific papers in agriculture for Brazil and selected countries, 1967

Countries	Ratios	
	Expenditures on Research	Number of Papers
Brazil:U.S.	0.012	0.020
Brazil:U.K.	0.157	0.080
Brazil:Canada	0.112	0.150
Brazil:Japan	0.072	0.200
Brazil:Mexico	2.449	1.698
Brazil:Indonesia	34.351	5.789
Brazil: India	0.375	0.096
Brazil:Israel	0.642	0.896

Source: Evenson and Kislev (1975:165-69).

There was a large increase in the number of papers published in Brazil in the seventies (Table 9), about twice the number published in the sixties. The data in Table 9 reflect a noticeable change in governmental support of agricultural research in the late sixties and seventies (Pastore and Alves, 1975) which grew out of the creation of a central coordinating agency. Even if the number of papers is a good proxy for the real effect of research on agricultural productivity, it is likely that the expansion in the seventies did not have a measurable effect on TFP for the period 1950-1976 because of the lag involved between the creation and application of new knowledge.

Credit should be a factor of paramount importance in explaining modernization and gains in productivity of the agricultural sector. For agricultural credit, data were more readily available than for research. Agricultural credit has increased steadily in absolute terms as well as in percentage of value added (Table 10). Indeed, from 1965 onward, it was the largest and fastest growing agricultural credit program among the LDC's and generated more credit than all the LDC's combined.

Credit for marketing should increase productivity by increasing the efficiency with which commodities are moved from the farms to the final consumers. This may not happen if market place owners have oligopsonistic power. In such a case, a greater access to credit by these buyers could have a depressing effect on farm gate prices and a disincentive toward improvement in agricultural productivity. Therefore a study focusing on the relationship between

Table 9. Number of scientific papers in agricultural research published in Brazil, 1927-1977

Years	Number of Papers
1927-29	157
1920-39	519
1940-49	1047
1950-59	1158
1960-69	1808
1970-77	2819

Source: Silva, Fonseca and Martin (1979:186).

agricultural credit and productivity, ideally, should separate credit for marketing, production and investment.

Although a complete time series on credit for marketing purposes was not available, estimates by Tendler (1969:7) from 1954 to 1968 were available. Her estimated values are presented in Table 11. One can see that agricultural credit for marketing was a respectable share in the total credit for agriculture, reaching 40.0 per cent of the total credit in some years and with an average share of 35.4 per cent for the whole period.

The government has provided large amounts of credit for improvements in agriculture. In 1975 credit exceeded value added (Table 10). One would expect a positive and significant association between credit and gains in productivity, via the acquisition of capital. However, this relationship does not only depend on the amount of total credit supplied but also on the kind of credit, its distribution, and its efficiency in use and administration.

Another important item in explaining productivity is the role of international trade. To compete in foreign markets a country has to be able to produce goods at a comparative advantage with its competitors. The more it decreases its cost, or increases efficiency in production, the more likely it is to have such an advantage. The role of government policy is fundamental. Governmental attitudes toward implementing international versus domestic trade not only affect agriculture productivity but can lead to differential rates of

Table 10. Value of Brazilian agricultural exports and credit as a percentage of value added in agriculture, 1950-1976

Year	E	C[a]	E/V	C/V
	(million cruzeiros)			
1950	24.6	4.1	39.6	6.6
1951	32.2	5.8	45.0	8.2
1952	25.9	8.8	30.7	10.4
1953	30.6	9.7	29.5	9.3
1954	41.4	25.3	31.3	19.2
1955	51.1	27.3	30.6	16.4
1956	54.7	33.0	28.4	17.1
1957	52.7	43.8	22.5	18.7
1958	53.0	53.7	20.4	20.6
1959	93.4	70.9	25.6	19.3
1960	120.4	101.4	23.9	19.9
1961	194.1	152.7	27.1	21.3
1962	242.7	267.2	18.9	20.8
1963	444.0	472.7	22.4	23.8
1964	907.8	979.3	22.1	23.8
1965	1605.3	1667.0	23.9	28.5
1966	3091.0	2117.7	37.8	30.9
1967	3321.5	3366.8	29.8	37.2
1968	4891.6	6373.0	35.3	55.2

Table 10. Continued

1969	7031.0	6489.0	39.6	45.2
1970	7316.4	9247.9	42.7	53.9
1971	8469.4	12869.7	35.5	53.6
1972	14112.0	18668.7	46.1	61.0
1973	22354.6	30333.9	34.0	68.5
1974	30104.3	48272.7	45.8	73.5
1975	37849.1	89997.1	43.0	102.4
1976	64638.4	130226.1	46.9	94.5

a) E stands for exports, C for credit, and V for value added. Source: Table A-1 for value added. Relatorio do Banco do Brazil, 1950-53, Doellinger et al. (1973:97), 1954-69, Silva, Fonseca and Martin (1979:155), 1970-76, for exports. Relatorio do Banco do Brazil, 1950-53, Tendler (1969:7), 1954-68, Series Estatisticas Retrospectivas (1977:126), 1969-76, for credit.

Table 11. Estimated agricultural credit for marketing purposes and as a percentage of total agricultural credit, 1954-1968

Year	Credit for Marketing (millions of 1968 cruzeiros)	Percentage of Total
1954	605.7	34.2
1955	554.1	32.8
1956	636.1	37.1
1957	739.7	36.6
1958	675.8	30.7
1959	673.6	31.9
1960	775.8	33.7
1961	929.7	37.1
1962	945.8	33.0
1963	1114.7	38.2
1964	1262.9	40.0
1965	1433.6	40.4
1966	1352.2	41.0
1967	1648.7	39.4
1968	1865.2	25.9

Source: Tendler (1969:7) and Table 10.

productivity growth among subsectors of the agricultural sector and among regions of the country.

The growth of the value of export crops as a proportion of total value of production has been steady, while growth for domestic crops has been erratic. This fact has encouraged the allocation of resources, including agricultural research, toward export crops in detriment to the domestic crops, has generated inflationary pressures in the internal market (Silva, Fonseca and Martin, 1979:176-80) and has led to imbalance in productivity between the export and domestic agricultural sectors. Another crucial point is that starting in 1966 the government has increasingly promoted the export of processed agricultural products. The consequence of this policy has been the emergence of a highly subsidized group of processors who, because of noncompetitive forces, can impose low prices for raw materials with the consequent negative effects on agricultural productivity (Graham and Barros, 1980:18).

As a percentage of value added in agriculture, the value of exports has grown since the early 1960's and has now reached levels exceeding those of the early 1950's (Table 12). These data point to a strong dependence of Brazil on agricultural exports to international markets.

Summary

Several conclusions emerge from the discussion of the data presented in this chapter. Growth in traditional inputs, such as land,

Table 12. Value of traditional export and domestic crops as a proportion of their value of production, 1962-1976

Year	VE/VPE[a]	VD/VPD[b]
1962	0.288	-
1963	0.342	0.016
1964	0.350	0.002
1965	0.267	0.020
1966	0.317	0.025
1967	0.309	0.009
1968	0.351	0.028
1969	0.355	0.014
1970	0.403	0.026
1971	0.357	0.025
1972	0.429	0.003
1973	0.530	0.002
1974	0.364	0.019
1975	0.463	0.018
1976	0.581	0.021

a) VE stands for value of exports and VPE for the value of total production of export crops, it includes: coffee, sugarcane, cotton, peanuts, soybeans, oranges, castor seed tobacco. b) VD stands for value of domestic crops exported and VPD for the value of total production of domestic crops, it includes: rice, banana, beans, manioc, onions, corn, tomatoes, potatoes, pineaple, sweet potatoes, grapes, wheat, coconut. Source: Silva, Fonseca and Martin (1979:178).

labor and tractors had the following behavior: capital experienced the fastest growth rate, followed by land, an abundant factor in Brazil, and labor showed a modest growth. These trends would indicate a movement toward modernization, as revealed by a substitution of capital for labor.

Modern inputs (fertilizers, pesticides and improved seeds) have been increasingly utilized, especially fertilizers. Despite declining and subsidized prices these items are still costly compared to prices in countries like the U.S. and Japan (Paiva, 1969:180-82). Also these inputs are mostly used in the production of export crops. Modernization of the production of basic food crops has been slow and this failure to modernize has added to inflationary pressures in the domestic sector.

Agricultural research has been increasing. International comparisons show that before the seventies Brazil played an intermediary position among developing countries. If estimates of a 6 to 7 year lag for research to affect production are correct, it is likely that the increase in research activity in the late sixties and seventies has little influence on productivity estimates in this study.[2] Exports have also increased steadily. However, this activity has contributed to a dual agricultural sector; i.e., a modern and profitable subsector dedicated to foreign markets and a traditional one dedicated to staple crops for domestic consumption. Credit increased

greatly from 1950 to 1976. However, not all of this credit was for basic agricultural production since an important share went for marketing.

Notes

1.This pattern includes the use of credit and duty free imports to establish marketing channels. Local industries are then encouraged with protectionist walls whence then increase the cost to users (Graham and Barros, 1980:8).

2. For evidence of this lag see, for example, White and Havlicek (1982:55).

CHAPTER IV

EMPIRICAL ESTIMATES

Total Factor Productivity

To estimate the growth in total factor productivity data on output or value added, primary inputs, and prices of the intermediate inputs were used.

A translog function was fitted to the agricultural sector as a whole. Primary inputs were land, labor, and fixed capital. Price of fertilizers from 1950 to 1976 provided the only complete series for intermediate inputs and is used as a proxy for modern inputs. Two techniques of estimation were used, ordinary least squares (OLS) and the maximum entropy approach (ME), developed by Theil (1982). Unlike sample moment matrix, the maximum entropy moment matrix is always positive definite. This fact makes this technique especially suitable to treat problems of undersized samples and multicollinearity. The results of the two methods are shown in Table 13.

An average growth in TFP for the whole period was estimated for purposes of a summary measure of performance and for international comparisons. Yearly growth was also estimated.

To obtain an estimate of average growth in value added the logarithm of single deflated value added was regressed on time. To find the change in the primary inputs a similar method was used. The

Table 13. Estimated parameters of the translog model on single value added, by ordinary least squares and maximum entropy approachs

Regressors	Ordinary Least Squares		Maximum Entropy
	Coefficient	Standard Error	Coefficient
constant	-260.566	184.475	-
ln R	5.099	12.329	-37.038
ln z_1	69.952	70.394	-2.757
ln z_2	65.435	141.647	10.040
ln z_3	-70.893	60.824	-10.609
ln R*ln R	0.240	0.281	-5.304
ln z_1*ln z_1	13.480	15.619	-2.518
ln z_1*ln z_2	-11.448	37.622	-0.541
ln z_1*ln z_3	-7.891	13.787	-0.474
ln z_2*ln z_2	-11.320	28.653	0.268
ln z_2*ln z_3	13.879	14.622	1.045
ln z_3*ln z_3	1.200	5.581	0.690
ln R*ln z_1	-1.925	3.913	3.508
ln R*ln z_2	0.057	3.849	-2.384
ln R*ln z_3	-1.292	1.577	5.507
R^2 = 0.96	$\bar{R}^2$ = 0.91		
n = 27, dependent variable was ln g			

a) g stands for SVA (based on Table A-1), it is measured in thousands of 1966-70 cruzeiros. R stands for the subsidized price of fertilizers, measured in 1966-70 cruzeiros (based on Table A-5). z_1 is the acreage of agricultural land in thousands of hectares (Table A-2). z_2 is the labor force engaged in agriculture, given in thousands of workers (Table A-2). z_3 is fixed capital in thousands of 1966-70 cruzeiros (Tables A-3, A-4 and A-5).
b) There is no way to estimate standard errors for the estimators derived from ME moments. For a discussion of ME moments see Theil (1982).

derivatives of the translog function, with respect to the primary inputs, evaluated at the geometric means of the variables, gave the weights for the change in the primary inputs.

Deflated value added increased, on the average, 3.1 per cent over the period 1950-1976, while growth in the primary inputs was 2.0 per cent. Therefore, the average increase of total productivity over the period was 1.1 per cent. This estimate is biased since it disregards changes in the price of intermediate inputs (equation (8)). However, after adding the weighted change in the price of the intermediate input, TFP changes only in the third decimal place. This situation arises because of the value of the growth rate of fertilizers price, which is negative but almost nil. This adjusted measure does not eliminate bias due to specification errors associated with not including prices of other intermediate inputs.

To obtain annual estimates of TFP growth, a first difference approach was used to evaluate the yearly changes in value added and in the primary inputs. The weights used were the derivatives of the translog evaluated at each point of time. The yearly changes in value added, primary inputs, and total factor productivity are given in Table 14 and are graphed in Figure 5. The average of these changes over the whole period for value added was 4.1 per cent. The weighted change in the primary inputs was 2.1 per cent and the average change of total factor productivity was 2.0 per cent.

There is considerable difference between the results of the two methods. With the first method, the growth in value added is

Table 14. Yearly change in value added, weighted sum of primary inputs and total factor productivity

Year	Yearly Change[a]		
	dV	dX	dTFP
1950/51	-0.0133	0.1147	-0.1280
1951/52	0.0529	0.1064	-0.0535
1952/53	0.1025	0.1597	0.0572
1953/54	-0.0325	0.0111	-0.0214
1954/55	0.0126	0.0224	-0.0098
1955/56	-0.0208	-0.0166	-0.0042
1956/57	0.1451	0.0318	0.1133
1957/58	-0.0012	0.0389	-0.0401
1958/59	0.0800	0.0284	0.0516
1959/60	0.0075	0.1881	-0.1806
1960/61	0.0277	-0.0649	0.0926
1961/62	0.1245	-0.0063	0.1308
1962/63	-0.0667	-0.0321	-0.0346
1963/64	0.0368	0.0048	0.0320
1964/65	-0.0007	0.0094	-0.0101
1965/66	-0.1730	0.0038	-0.1768
1966/67	0.0596	0.0136	0.0460
1967/68	0.0893	0.0114	0.0779
1968/69	0.0226	0.0116	0.0110
1969/70	-0.0719	-0.1580	0.0861

Table 14. Continued

1970/71	0.1169	0.0129	0.1040
1971/72	0.0426	0.0136	0.0296
1972/73	0.2168	0.0126	0.2042
1973/74	0.1460	0.0136	0.1326
1974/75	0.0786	0.0581	0.0205
1975/76	-0.0144	-0.0054	-0.0090

a) $dV = (V_t - V_{t-1})/V_t$, dX is the weighted yearly change in the primary inputs and dTFP is the yearly change in TFP.

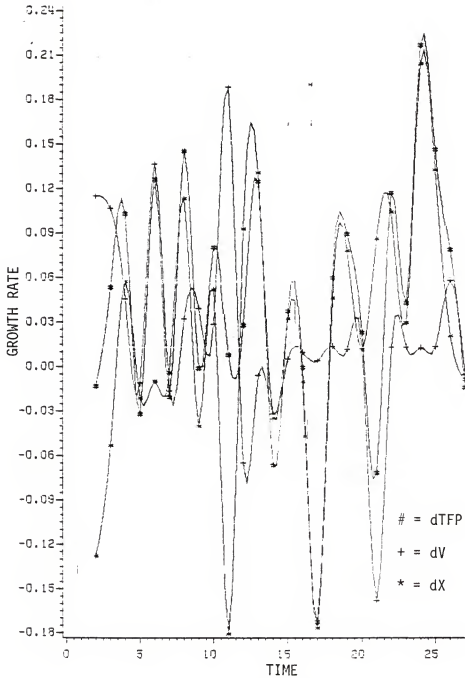

Figure 5. Growth rates of TFP, weighted sum of inputs, and value added

obtained by assuming that it has an exponential growth over time; i.e.,

$$V = \alpha e^{Bt}$$

then

$$dV/V = d\ln V/dt = \beta$$

With the second method, yearly growth in value added is approximated by first differences; i.e.,

$$dV/V \simeq (V_t - V_{t-1})/V_t$$

and the average over the whole period is taken to compare to β. The result is that the average in the second case is higher than β.

A similar method was used to calculate the growth in primary inputs. To illustrate this with one input, X,

$$dX = (d\ln X/dt)\, X$$

and the geometric mean of X was used for an average estimate. In the second method one has,

$$dX \simeq X_t - X_{t-1}$$

One should note that in the first method, after some simplifications, the expression resulting in TFP is equivalent to

$$q = \beta - \theta\alpha$$

where θ stands for a vector of derivatives of SVA with respect to the primary inputs and α stands for the vector of growth rates. In the second method, on the average

$$q \simeq \beta^* - \theta^*\alpha^*$$

where β^* is the average of $(V_t - V_{t-1})/V_t$, and $\theta^*\alpha^*$is the average of θ $(X_t - X_{t-1})/X_t$. $\beta^*$is greater than β and $\theta^*\alpha^*$ is greater than $\theta\alpha$. Moreover, the increase in these two quantities is not proportional,

since the transformation is not linear. Therefore one should not expect equality between the two results.

Factors Associated with the Growth in TFP

Yearly estimates of TFP were regressed on agricultural credit and exports to see how much of the variation in TFP was associated with these two variables. Here exports were treated as a proxy to represent the change in technology required to compete in international markets, and credit represented access to modern inputs. Both variables were taken as a percentage of value added and differences were taken between contiguous years.

The results of the regression (Table 15) show that a 1 per cent increase in the export/value added ratio caused a change of 0.27 per cent in total productivity, a much stronger effect than that due to the agricultural credit/value added ratio which was 0.06.

Though there remains a specification error, two conclusions are suggested by these results. Firstly, exports have a stronger effect on productivity. This fact basically reflects the historical background of Brazilian agriculture. Leading sectors have always been devoted to international competition and trade which induces technological changes. Secondly, with respect to agricultural credit to buy modern inputs such as fertilizers, pesticides, seeds, storage and machinery, it is reasonable to assume that those modern inputs are the main inductors of change in productivity. If so, the estimated effect of agricultural credit may be underestimated. However, some facts are

Table 15. Estimated coefficients of the regression of yearly changes in total factor productivity on lagged exports/value added and credit/value added ratios

Variable [a]	Coefficient	Standard Error
Intercept	0.026	0.020
E/V.A.	0.271	0.252
C/V.A.	0.062	0.266
$R^2 = 0.47$	$\bar{R}^2 = 0.41$	
n = 24		

a) V.A. stands for value added, E for exports and C for credit. The data were from tables 14 and 10.

hidden behind this logical chain. The access to credit in Brazil is biased in favor of large farmers whose use of modern technology is not dependent on government credit. Credit policies may not have the intended impact because the credit simply substitutes for the own financed capital of large farmers. In Brazil, also, there is evidence that agricultural credit is diverted from its basic purpose of purchasing modern inputs and is used instead to expand land ownership, to speculate, and to buy consumption goods.

Evidence of large farmers getting greater access to credit is provided by White and Seabra (1973), Tommy (1971) and Nehman (1973). On the other hand, Donald (1976) in his findings has shown that agricultural credit has had small impact on small farm productivity or income. All these studies stress the fact that capital does increase with the rise in credit but that credit is not effectively used on all types of farms.

Finally, evidence of diversion of agricultural credit from its proper use is not easy to find in official statistics. However, what was called the "manioc scandal," largely reported by the press (Jornal do Brasil, 1982, December, 10), provides some insights into the extent of this problem.

Elasticities of SVA

The sensitivity of value added to the change in the quantity of primary inputs and to the price of fertilizers was estimated as elasticities and are shown in Table 16.

Table 16. Elasticities of single value added function with respect to land, labor, fixed capital and normalized price of fertilizers

Item	Elasticities[a]	
	From OLS	From ME
Normalized Price of Fertilizers	0.33	0.17
Land	- 1.44	- 1.01
Labor	1.49	0.42
Fixed Capital	0.64	1.67

a) Elasticities were estimated at the geometric means of the variables using coefficients reported in Table 13.

The estimates indicate that value added is more sensitive to the change in labor used. A 1 per cent increase in the labor used caused a 1.49 per cent increase in value added, an elastic response. By the same token an increase of 1 per cent in the stock of fixed capital used in agriculture caused a 0.64 per cent increase in value added. The positive response to change in price of fertilizers and the negative response of value added to change in land used was unexpected. Ahmad (1982:82) found a negative response of single value added to change in land used. If true, these results suggest that land is being overused and that farmers are not short-run profit maximizers but rather have other objectives which are embedded in land ownership structure and associated cultural values, cultivation practices, and perhaps other factors.

Another possible explanation for these unexpected results links the negative response of an increase in land to the positive response to an increase in fertilizers' price. Fertilizer and land are substitutes with land being extensively used in Brazilian agriculture and fertilizers being used parsimoniously. The signs of these two elasticities are consistent in that they imply that farmers are overusing the land resource. If true, these results may persist until the land frontier is closed.

To test the possibility of a poorly conditioned matrix causing distortion in the sign of the derivatives of SVA, the maximum entropy approach, ME, was used to reestimate the parameters. The new estimated elasticities are shown in Table 16. The similarity of the OLS and ME

results with respect to the signs of the estimates suggest that multicollinearity is not responsible for the unexpected sign in the fertilizer and land elasticities.

Derived Demand for Fertilizers

Another important concept that can be estimated from the estimated value added function is the derived demand for fertilizers and the elasticities of fertilizers with respect to its price and with respect to the primary inputs.

From equation (6) one knows that the negative of the derivative of SVA with respect to the price of the intermediate input is the demand for the intermediate input. This last expression is a function of the quantities of the primary inputs and the price of the intermediate inputs. From this function one can measure the producers response to change in the primary inputs and to the price of fertilizers through the respective elasticities.

These elasticities are shown in Table 17 and they indicate that a 1 per cent increase in the price of fertilizers brings about a decrease of 0.72 per cent in the demand for fertilizers. Similarly a 1 per cent increase in the quantity of labor would lead to a 0.17 per cent increase in the demand for fertilizers. Identical reasoning shows that the elasticity with respect to capital was 3.83. On the other hand, a 1 per cent increase in the acreage of land would lead to a decrease of 5.68 per cent in the demand for fertilizers. This estimate suggests that occupation of new land is not associated with a

Table 17. Elasticities of the derived demand for fertilizers with respect to its price and the primary inputs

Item	Elasticity[a]
Normalized Price of Fertilizers	- 0.72
Land	- 5.68
Labor	0.17
Fixed Capital	3.83

a) Elasticities were estimated at the geometric means of the variables using OLS coefficients from Table 13.

modernization in the method of production and supports the claim of Graham and Barros (cited previously on Chapter I).

Shadow Prices of Primary Inputs

The shadow prices of the primary inputs can be estimated from the estimated SVA function, as given in equation (5). Using the estimated parameters of Table 13 and equation (5) the shadow price functions for land, labor and capital are:

$W_1 = (69.95 + 13.48 \ln z_1 - 11.45 \ln z_2 - 7.90 \ln z_3 - 1.92 \ln R)\ V/z_1$,

$W_2 = (65.43 - 11.45 \ln z_1 - 11.32 \ln z_2 + 13.88 \ln z_3 + 0.06 \ln R)\ V/z_2$, and

$W_3 = (-70.89 - 7.90 \ln z_1 + 13.88 \ln z_2 + 1.20 \ln z_3 + 1.30 \ln R)\ V/z_3$.

One should note that these shadow prices, evaluated at the geometric means of the variables, are simply the elasticities of SVA with respect to the primary inputs (Table 16) multiplied by a constant (V/z_i). These figures are presented in Table 18. Also, the standard error of each estimated parameter in the equations above can be read directly from Table 13.

Normally there should be a negative relationship between the quantity of an input and its shadow price. The results are consistent with this expectation for labor but not for land and capital. In a perfectly competitive equilibrium system the shadow price would be identical to the value of the marginal product of the input. The

Table 18. Estimated shadow prices of primary inputs in Brazilian agriculture

Item	Shadow Price[a]
Land	-2.22
Labor	2.44
Fixed Capital	0.86

a) evaluated at the mean of the variables.

positive relationship between the shadow price of capital and the quantity of capital used suggests that capital usage could be in the range of an increasing marginal product for capital; i.e., in stage 1 of the production process. The use of capital in Brazil is quite low but it is questionable whether Brazil's agriculture is operating in an area of increasing returns to capital. This situation is more unlikely for land which has been used extensively in Brazilian agriculture.

The relationships between the shadow price of land and the quantities of labor and capital brought into production were both positive, which indicate that labor and capital are substitutes for land. The relation between the shadow price of labor and the quantity of capital was also positive, which suggests that these inputs are substitutes. This last outcome is a recognized pattern in an agricultural sector starting to develop; i.e., the increasing application of capital releases labor from agriculture. Calculation of the relations above using ME estimated parameters did not substantially change the conclusions.

International Comparisons

Table 19 provides estimates which permit one to compare productivity measures obtained in this study with those from other developing and tropical countries. The estimation methods used differ among countries. Also the periods of each analysis are different but overlapping.

Table 19. International comparisons of total factor productivty

Country and Period	Growth Rate			
	Output	Value Added	TFP	
			Output basis	Value Added basis
Brazil				
1950-76	.	3.1	.	1.1
Mexico				
1940-65	4.7	.	0.4	.
1954-65	3.7	.	0.7	.
Indonesia				
1950-78	.	2.8	.	0.6
Philippines				
1950-69	4.0	3.8	0.7	1.6
Taiwan				
1946-70	5.6	4.8	0.7	1.5
Korea	4.4	4.3	1.9	2.8

Source: Tables 1 and 13 for Brazil; Hertford (1971:17-18) for Mexico; Ahmad (1982:146) for Indonesia; David and Barker (1979:131) for the Philippines; Lee and Chen (1979:72) for Taiwan and Ban (1979:101) for Korea.

Mexico is perhaps most comparable to Brazil not only because of the hemisphere proximity but for a number of other similarities. In a study using a Cobb-Douglas production function, obtained from census years, the growth in productivity from 1940 to 1965 was 0.4 per cent, which is below the growth of Brazilian productivity during the period 1950-76. For the period 1954-65 growth in total productivity for Mexican agriculture is a bit below that for Brazilian agriculture from 1950 to 1976. One should stress that the estimates for Mexican agriculture were obtained by using growth in output instead of value added. Measures of TFP based on value added are generally higher than those based on output. Therefore, one would expect that a study based on value added for Mexico would provide a slightly higher growth measure for TFP and consequently closer to the Brazilian estimate. Mexican agriculture has had a development experience similar to that for Brazil.

The Indonesian study by Ahmad, which used similar variables and a similar estimation technique, yielded a 0.6 per cent growth estimate. Growth in value added was about 2.8 per cent in Indonesia and 3.1 per cent in Brazil which suggests a very close weighted growth in the inputs for the two countries.

For the other three countries, studies were based on accounting procedures; i.e., indexes of inputs and outputs were constructed without resorting to estimation of production or value-added functions. The Brazilian estimate is well below the estimated growth for Taiwan, Philippines, and Korea.

The general conclusion drawn from these international comparisons is that figures on TFP for developing countries in tropical areas vary with the method of estimation used as well as with the definition; i.e., output or value-added measure. One can see that the TFP measures based on value added are higher when accounting procedures are utilized than those based on econometric estimation. If this discrepancy is due to difference in method or to policies and other exogenous variables is an open question, but one should keep in mind that accounting procedures may undervalue the factor shares of some inputs (Hertford, 1971:18). The comparison here seems to support Hertford's claim. When the estimation technique is different but TFP is based on output, estimated growth is closer but with only the result for Mexico to compare to the three other countries this conclusion is quite tenuous.

Mexico and Brazil have a similar cultural and technological background as well as a similar endowment of natural resources. Both countries have greater difference with the Asian countries. Therefore the estimates of productivity for Mexico, Brazil and Indonesia cannot be attributed solely to techniques of measurement. Policies and other exogenous variables affect the measures. It is uncertain whether the high growth in productivity for Korea, Philippines, and Taiwan is due to differences in techniques of measurement or to real factors.

Average growth rates of partial productivities of land and labor used in agriculture for the same countries, except Mexico, are presented in Table 20. All the Asian countries have a very high growth

Table 20. Growth of partial productivities of land and labor in selected countries, various periods

Country and Period	Rate of Growth (Value Added basis)	
	Land	Labor
Brazil 1950-76	0.09	0.61
Indonesia 1950-78	1.81	1.93
Philippines 1950-69	1.20	1.40
Taiwan 1946-70	4.40	3.80
Korea 1953-69	1.63	1.28

Source: Tables A-1 and A-2 for Brazil; Ahmad (1982:95) for Indonesia; David and Barker (1979:135) for the Philippines; Lee and Chen (1979:79) for Taiwan, and Ban (1979:103) for Korea.

rate of partial productivity for both factors, when compared to Brazil. Since these average rates indicate the growth rate of value added diminished by the growth rate of the respective input, with other things held constant, the results suggest that capital had a stronger contribution to growth in Brazil than in Indonesia.

CHAPTER V

REGIONAL ANALISYS

TFP

Using the census years of 1960, 1970 and 1975, nine states for the Northeast region and seven states for the South, the cost function, defined in Chapter II, together with the shares of land and capital were estimated using Zellner's seemingly unrelated regressions method. The estimated parameters are presented in Table 21. From these parameters, and the definitions given previously, an attempt was made to quantify the elasticities of substitution and price elasticities for the inputs as well as the growth in TFP for the two regions.

The results for TFP are presented in Table 22. In Chapter IV the growth in total productivity for Brazil amounted to 1.1 per cent (using the average measure) over the period 1950-1976. Therefore, it would be reasonable to expect similar results for the change in productivity for the two regions, since they are the major ones in the country, and it is unlikely that data for the 1950's would alter the results to any great extent. Unfortunately, this was not the result. The growth in TFP in the Northeast was estimated to be slightly negative while that for the South was small but positivive.

The definition of growth in TFP, using the cost function is

$$q = E_{Ft} = E_{ct} / E_{cy}$$

Table 21. Estimated parameters of the translog cost function for the South and Northeast Brazil using data from census years of 1960, 1970 and 1975

	South		Northeast	
Variable[a]	Coefficient	Standard Error	Coefficient	Standard Error
Constant	-21.953	13.605	-3.161	2.204
ln V	4.535	3.188	0.648	0.593
ln p_1	5.004	2.853	-2.407	0.482
ln p_2	0.392	2.539	4.211	0.640
ln p_3	-4.396	4.387	-0.803	0.549
ln V*ln V	-0.156	0.171	0.014	0.039
ln p_1 *ln p_1	-0.192	0.412	0.340	0.073
ln p_1 *ln p_2	-1.475	0.976	0.100	0.110
ln p_1 *ln p_3	1.101	1.162	-0.127	0.092
ln p_2 *ln p_2	0.231	0.433	-0.444	0.097
ln p_2 *ln p_3	1.143	0.823	0.450	0.110
ln p_3 *ln p_3	-0.808	0.884	-0.319	0.046
ln V*ln p_1	-0.123	0.283	0.004	0.066
ln V*ln p_2	-0.033	0.271	-0.284	0.070
ln V*ln p_3	0.157	0.419	0.280	0.073
t	-0.054	0.034	0.002	0.005

a) V stands for value added (Tables B-1, B-2); p_1 is price of land (Tables B-5 and B-6); p_2 is price of labor (Tables B-5 and B-6); p_3 is price of capital (Tables B-5 and B-6); t is a time shifter; and C stands for total expenditures, or cost (Tables B-3 and B-4). All variables were measured in 1965-67 cruzeiros.

Table 22. Growth in total factor productivity for the South and Northeast regions of Brazil as estimated from census data for 1960, 1970 and 1975

Region	E_{ct}	E_{cy}	Growth in TFP [a]
Northeast	- 0.0027	0.7631	- 0.0035
South	0.0546	2.9265	0.0186

a) Estimates were computed at the means of the variables from coefficients in Table 21.

where this notation was defined in Chapter II. The elasticities of cost with respect to value added (E_{cy}) were 0.76 and 2.92 for the South and the Northeast, respectively. Although similar estimates were not available for other countries or regions for comparison, it seems consistent in the short-run to have an inelastic relationship, which reflects decreasing returns to scale, for the underdeveloped region and the reverse for the developed one.

The rate of total cost diminution was near zero but slightly negative for the Northeast. This result suggests that there was no improvement in technology or efficiency, in other words, the cost of production failed to diminish through time. The sign of E_{cy} is positive for the two regions, therefore the differences in the direction of gains in productivity should be explained through the rate of total cost diminution. A negative E_{ct} for the Northeast and a small but positive E_{ct} for the South shows that the Northeast is losing its efficiency in absolute as well as relative terms. As a consequence, a pattern of widening inequality between the agricultural sectors of the two regions has been occurring.

Elasticities of Substitution and Demand

Using equations (10), (11) and (12), elasticities of substitution, own and cross-demand elasticities for the inputs were derived from the parameters of the cost functions. Tables 23 and 24 give the values for these elasticities for the South, Tables 25 and 26 give them for the Northeast. Tables 27 and 28 show corresponding

Table 23. Elasticities of substitution in the South of Brazil

	Pair of Inputs [a]		
	Land-Labor	Land-Capital	Capital-Labor
Elasticity	- 25.59	16.30	7.43

a) Elasticities were estimated at the means of the variables from coefficients in Table 21.

Table 24. Own and cross-elasticities of the demand for inputs in the South of Brazil

	Land	Labor	Capital [a]
Land	-2.130	-9.450	7.820
Labor	-3.830	-0.003	3.560
Capital	2.440	2.750	-2.200

a) Elasticities were estimated at the means of the variables from coefficients in Table 21.

Table 25. Elasticities of substitution in the Northeast of Brazil

	Pair of Inputs [a]		
	Land-Labor	Land-Capital	Capital-Labor
Elasticity	2.33	- 4.05	4.05

a) Elasticities were calculated at the means of the variables from coefficients in Table 21.

Table 26. Own and cross-elasticities of demand for inputs in the Northeast of Brazil

	Land	Labor	Capital [a]
Land	2.11	1.54	-0.90
Labor	0.26	-1.00	0.90
Capital	-0.35	2.69	-2.21

a) Elasticities were estimated at the means of the variables from coefficients in Table 21.

Table 27. Elasticities of substitution in the U.S. agricultural sector

	Pair of Inputs		
	Land-Labor	Land-Machinery	Capital-Machinery
Elasticity	0.20	1.21	0.85

Source: Binswanger (1974:383).

Table 28. Own and cross-elasticities of demand for inputs in the U.S. agricultural sector

	land	Labor	Machinery
Land	-0.33	0.06	0.17
Labor	0.03	-0.91	0.12
Machinery	0.18	0.25	-1.08

Source: Binswanger (1974:383).

elasticities for the agricultural sector in the U.S., as estimated by Binswanger (1974:383).

According to the results in Table 23 for the South, land and labor are complements whilst labor and capital are substitutes. The first result does not deserve especial attention and the explanation for the second is the commom historical pattern exhibited by developing regions. With the increasing mechanization of the agricultural sector an increasing proportion of the labor force shifts to other occupations. The elasticity of substitution between land and capital has a positive sign. Land in the South has become a limiting factor with the closing of the agricultural frontier and capital in the form of chemicals and fertilizers is increasingly being substituted for land.

The cross-elasticities, given in Table 24, follow the sign of the elasticities of substitution, but their magnitudes reflect the relative share of the input (Binswanger, 1974:384). The own-price elasticity for labor, land and capital have the correct sign. The demand for land and capital were both elastic with almost the same estimated elasticities. This result perhaps reflects the comparative importance of these two factors in agricultural production in the South.

For the Northeast a different pattern is suggested. According to the results in Table 25 labor and land are substitutes. This fact does not seem to fit commom intuition but the peculiarities of the Northeast provide a plausible explanation. The difficulties in getting rid of sharecroppers combined with the unavailability of wage workers

make the admission of additional labor by farmers rare in the Northeast. Probably the additional labor needed is provided by family labor and longer working hours. This fact could be reflected in the data and show a positive elasticity of substitution between land and labor. One should remember that the data used in the analysis accounts only for the number of people employed in agriculture and not for the labor effectively used.

A change in product mix in the Northeast is another hypothesis that may help to explain the estimated relationship between land and labor in this region. Land in sugarcane production has been falling relative to land in pastures, and cattle production uses much less labor per unit of land than does sugarcane.

Land and capital are complements, labor and capital are substitutes. The first result is more or less intuitive and its difference from the result for the South is due to the relative abundance of land in the Northeast. The substitutability between labor and capital in the Northeast reinforces the thesis that mechanization displaces labor. Although the elasticity of substitution between labor and capital is positive for the Northeast it is about half of the value of the same elasticity for the South.

Estimated own and cross-price elasticities are given in Table 26. The estimated own-price elasticities for capital and labor have the right signs. As in the South the demand for capital in the Northeast is elastic with little difference in the size of elasticities for the two regions. The demand for labor presented a unitary elasticity and may

reflect fewer alternatives for an unskilled labor force. The estimated own-price elasticity for land had the wrong sign.

The only comparable results that could be found for elasticities of substitution in Brazil were those by Scandizzo and Barbosa (1977). In their paper an analysis of the agricultural sector in the Northeast was also presented. Applying a CES production function, they found an elasticity of substitution between labor and capital near unity. Although the result in this work is consistent in sign with theirs the magnitude is substantially larger.

To summarize the results labor and capital for the two regions are substitutes for each other with the elasticity of substitution for the Northeast being about half of that for the South. This fact seems to reflect a lesser degree of sophistication in the process of mechanization in the Northeast. Capital and land in the South are used as substitutes, perhaps reflecting the constraint on land with the closing of the agricultural frontier combined with the increased use of chemicals and fertilizers, whilst they are complements in the Northeast where land is abundant. Finally, land and labor are complements in the South, which is the normal case in empirical studies, but they are substitutes in the Northeast, a result inconsistent with standard expectations. This may be due to the peculiar kinds of contract between farmers and sharecroppers in the Northeast and a lack of wage workers which prevents farmers from readily hiring new labor.

Concerning the own-demand elasticities for the inputs the elasticity for capital is roughly equal for the two regions, showing the importance of this factor of production in both. The estimated elasticity of demand for labor is greater in the Northeast indicating fewer alternative allocations for an untrained labor force. The demand for land is elastic in the South but the estimated elasticity of demand for the Northeast was inconsistent in sign.

Use of Traditional Inputs and Output Growth

Several reasons can be given to justify the regional differences in TFP, factor usage and pattern of substitution. Following the scheme delineated in Chapter III, the role of traditional and modern inputs, exports, credit and research is contrasted for the two regions. Also the growth in specific crops is examined to see the pattern of specialization in the two regions.

Several differences can be detected in the use of traditional inputs in the two regions. The labor force in the Northeast increased by 13.6 per cent between 1960 and 1970, 15.4 per cent between 1970 and 1975, and 31.2 per cent for the whole period (Table 30). In the South those same percentages amounted to 5.2, 10.1 and 15.9, respectively (Table 29). In absolute terms the labor force in the two regions were roughly equal in 1975 but the Northeast had a share of 30.0 per cent in the total population and the South has a share of 60.2 per cent (Series Estatisticas Retrospectivas, 1977:38). The South produced about 80.0 per cent of all farm goods. These figures suggest an abundance of labor

Table 29. Amount of land, labor and capital used in agriculture in the South of Brazil, in 1960, 1970, and 1975

Year	Input		
	Land (1000 ha)	Labor (1000 workers)	Capital (1000 tractors)
1960	84135.2	7742.3	55.5
1970	86992.8	8151.2	147.1
1975	118635.9	8977.3	277.2

Source: Censo Agropecuario do Brasil (1960, 1970) and Sinopse Preliminar do Censo Agropecuario (1982).

Table 30: Amount of land, labor and capital used in agriculture in the Northeast of Brasil, in 1960, 1970, and 1975

Year	Input		
	Land	Labor	Capital
	(1000 ha)	(1000 workers)	(1000 tractors)
1960	21043.7	6659.1	3.1
1970	38197.9	7568.8	7.2
1975	78690.4	8738.7	15.0

Source: Censo Agropecuario do Brasil (1960, 1970) and Sinopse Preliminar do Censo Agropecuario (1982).

Table 31. Regional and national wage indices for Brazilian agriculture by regions, 1966-1975

Year	Region[a]		
	Northeast	South	Brazil
		(1966=100)	
1966	100.0	100.0	100.0
1967	125.0	134.0	134.0
1968	146.0	159.0	160.0
1969	172.0	195.0	208.0
1970	214.0	237.0	251.0
1971	269.0	284.0	316.0
1972	322.0	366.0	373.0
1973	417.0	479.0	487.0
1974	649.0	660.0	681.0
1975	839.0	912.0	920.0

a) Includes only the wage of permanent workers.
Source: Precos Pagos aos Agricultores (several issues).

Table 32. Daily real rural wages paid in the South of Brazil for selected states, 1966-1975

Year	State			
	S. Paulo	M. Gerais	R.G. do Sul[a]	Parana
		(cruzeiro/day)		
1966	5.75	4.34	7.09	6.84
1967	5.49	5.79	6.78	6.35
1968	6.46	4.51	6.80	5.83
1969	5.99	4.54	6.49	5.85
1970	6.80	4.42	6.72	6.03
1971	7.04	4.65	6.94	6.77
1972	8.00	5.03	7.43	6.38
1973	8.84	6.55	8.56	7.43
1974	10.53	8.08	9.81	9.52
1975	10.53	8.81	10.54	10.85

a) Measured in 1971 cruzeiros.
Source: Silva, Fonseca and Martin (1979:219-37).

Table 33. Daily real rural wages paid in the Northeast of Brazil for selected states, 1966-1975

Year	State		
	Ceara	Pernambuco (cruzeiro/day)[a]	Bahia
1966	3.25	3.86	4.31
1967	3.22	4.45	4.32
1968	3.10	4.18	4.42
1969	3.17	3.64	4.22
1970	3.03	3.38	4.58
1971	3.36	3.45	4.89
1972	3.52	3.58	4.70
1973	4.17	4.24	5.59
1974	6.06	6.35	7.50
1975	5.88	6.78	8.36

a) Measured in 1971 cruzeiros.
Source: Silva, Fonseca and Martin (1979:219:37).

in the Northeast but a labor low in productivity. This result is due in large part to a lack of investment in human capital. The wages paid in the two regions are becoming increasingly unequal. Table 31 shows the increase in wages for the two regions and for the whole country. The difference for the period 1966-1975 favored the South by 73.0 per cent. To give an idea of what this difference amounts to, Tables 32 and 33 depict the absolute real wages in the two regions, for selected states and years. The comparison shows that the daily wages in the South are considerably higher.

The degree of mechanization, approximated by the number of tractors, gives a more striking view of disparities between the agricultural sectors in the two regions (Tables 29 and 30). Although the percentage growth shows little difference, it was 398.0 per cent in the South and 381.0 in the Northeast, the regional shares in the total number of tractors in Brazilian agriculture (Table 34) were quite different. In 1975 85.8 per cent of the tractors were in the South compared to only 4.6 per cent in the Northeast.

Another significant difference is the percentage of irrigated land, shown in Table 35. Although the percentage of irrigated land is negligible in Brazil and in the two regions, the Northeast, a semi-arid region subject to constant severe droughts, has less than half as much irrigated land as the South.

According to Table 29 land increased by 41.0 per cent between 1960 and 1975 in the South. The greater part of this growth took place in the seventies. For the Northeast, the total growth in the same

Table 34. Number of tractors in the Northeast and South of Brazil as a percentage of the total number of tractors in Brazilian agriculture, 1960, 1970 and 1975

Year	Region	
	Northeast %	South %
1960	5.1	90.6
1970	4.3	88.7
1975	4.6	85.8

Source: Censo Agropecuario do Brasil (1960, 1970, and 1975).

Table 35. Regional and national percentages of agricultural irrigated land in Brazil, 1970 and 1975

Year	Region		
	Northeast %	South %	Brazil %
1970	0.16	1.31	0.27
1975	0.21	1.64	0.34

Source: Censo Agropecuario do Brasil (1970 and 1975).

period was 273.0 per cent (Table 30), this growth having taken place mostly in the first half of the seventies. This seems to fit the explanation given to the substitutability between land an capital in the South. Moreover, if one disaggregates the land by types of use it can be seen that most of the land growth in the Northeast was due to increases in pastures. Pasture land grew 361.9 per cent in the Northeast between 1960 and 1975 against 49.6 per cent in the South (Tables 29, 30 and 36).

If one compares the growth in selected crops for the two regions, a pattern of differing degrees of specialization emerges (Table 37). Export crops in the South grew three times more in the sixties than the Northeast and twice more in the seventies. The domestic crops grew more in the Northeast. These facts reveal the basic duality between the two regions. The South specializes in profitable export crops, produced with modern technology and higher productivity, and the Northeast remains dedicated to a traditional agriculture of subsistence. This pattern of duality is worsening.

The Role of Research, Exports and Credit

The regional inequality carries over in agricultural research as indicated by comparing the number of scientific papers published. The number of papers in The Northeast was 48.0 per cent of the number in the South during the sixties and 34.0 per cent in the seventies (Table 38). The gap between scientific production in the Northeast and the South is widening. Furthermore it is likely that the quality of

Table 36. Area with annual and perennial crops in the Northeast and South of Brazil, in 1960, 1970 and 1975

Year	Region	
	Northeast	South
	(1000 ha.)	(1000 ha.)
1960	6385.6	20528.4
1970	10322.8	20640.8
1975	10977.1	23422.9

Source: Censo Agropecuario do Brasil (1960, 1970, and 1975).

Table 37. Rate of growth of agricultural commodities by selected crops and regions, 1960-69 and 1970-79

Year	Region			
	South		Northeast	
	Export crops	Domestic crops	Export crops	Domestic crops
	%	%	%	%
1960-69	13.2	1.7	3.9	2.4
1970-79	7.4	4.3	3.1	5.1

Source: Graham and Barros (1980:2).

Table 38. Number of scientific papers published in agricultural research in Brazil, by region, 1960-69 and 1970-79

Years	Region	
	Northeast	South
1960-69	111	231
1970	413	1192

Source: Silva, Fonseca and Martin (1979:186).

research in the South is superior because of better training, material support and academic tradition (Ruff and Missiaen, 1975:52). Also, agricultural research in the Northeast is more concentrated toward a few commodities, especially cocoa.

Agricultural credit is another factor in the inequality between the two regions. This factor is tied to political decisions toward the agricultural sector. About 90.0 per cent of agricultural credit in Brazil is supplied by official banks. Credit to help alleviate interregional inequalities is being allocated to the Northeast. The share of credit allocated to the Northeast varied between 10.0 and 14.0 per cent during the period 1960 to 1975 and showed a tendency to decrease (Table 39). The share of total credit for the South also had ups and downs. this share comprised more than 75.0 per cent of total credit and increased between the initial and terminal years (Table 39). It is clear that agricultural credit has not been used to reduce the gap between the two regions. The declining share of the Northeast points to the fact that the credit policy has helped to perpetuate, or worsen the dual situation between the regions.

It was not possible to find reported data for agricultural exports from the two regions. However, data to estimate the value of the main products exported from the Northeast for the years 1960, 1965, 1970 and 1975 were available. And, since agricultural exports from the North and Central regions were quite small, a comparison of the Northeastern region to the total Brazilian agricultural exports in essence provides a comparison with the South. Table 40 shows that this

Table 39. Agricultural credit by region as a percentage of total agricultural credit in Brazil, 1967-1975

Year	Region	
	Northeast	South
	%	%
1967	14.7	74.9
1968	13.5	75.0
1969	13.7	77.7
1970	10.7	81.7
1971	12.9	78.7
1972	12.2	77.3
1973	11.4	78.8
1974	11.6	78.6
1975	12.7	75.9

Source: Tendler (1969:23), Series Estatisticas Retrospectivas (1977:126).

share has been increasing during the whole period, from 2.9 per cent in 1960 to 31.4 per cent in 1975. Some precaution should be taken in interpreting this share. First, most of the products exported by the Northeast had some industrial contribution added to their value, which overestimated the share to agriculture. Secondly, data about interregional trade can reveal that what is gained in the international market may be offset by the agricultural transactions with other regions.

All the products listed in Table 40 are traditional export crops with the largest proportion coming from sugarcane and cocoa. In the production of cocoa one would expect some gain in productivity, because of good research support and modernization in production. Since cocoa is mostly produced in the Northeast, gains in productivity for this crop would contribute to the region. For sugarcane, the product with a larger share in exports, the situation is different. The South, mainly Sao Paulo, has obtained larger gains in productivity for this crop than the Northeast. Therefore, gains in productivity, through export incentives, for this crop would not reduce regional disparities. Sisal and carnauba, with a good proportion in exports, had no improvement in technology during the period studied.

The Role of Modern Tangible Inputs

The role of modern inputs is examined by using data for fertilizer usage and expenditures for seeds and pesticides. Fertilizers usage data were available by years from 1960 to 1975. Data on seeds and

Table 40. Value of the main products exported from Northeast Brazil as a percentage of Brazilian agricultural exports, selected years

Year	Value of Exports[a]
	%
1960	2.96
1965	16.44
1970	19.55
1975	31.45

a) The products exported by the Northeast include: cocoa and its associated derivatives, sugar, castor seed oil, sugarcane syrup, tobacco leaves, sisal and its derivatives, carnauba wax and cashewnuts.
Source: Nordeste: Analise Conjuntural (1980:213) and Table 10.

Table 41. Fertilizer usage in the Northeast and South of Brazil with percentages of total usage, 1960-1975

Year	Region			
	Northeast[a] (1000 t.)	%	South[b] (1000 t.)	%
1960	23.9	7.9	275.0	92.1
1961	19.6	7.9	227.5	92.1
1962	21.3	8.9	215.8	91.1
1963	24.5	7.8	289.5	92.2
1964	22.6	8.8	233.0	91.2
1965	20.9	7.2	268.9	92.8
1966	27.9	6.4	252.6	93.6
1967	40.4	9.0	404.1	91.0
1968	38.3	6.8	523.0	93.2
1969	52.4	8.3	577.9	91.7
1970	73.5	7.4	925.5	92.6
1971	95.0	8.2	1069.9	91.8
1972	151.5	8.7	1595.0	91.3
1973	141.4	8.4	1537.6	91.6
1974	169.7	9.3	1564.9	90.7
1975	135.3	6.9	1842.3	93.1

a) Northeast plus the North. b) Includes the states of Mato Grosso and Goias.
Source: Paiva, Schattan and Freitas (1976:309-10), Agricultura em Sao Paulo (1980:105).

pesticides were more limited. The agricultural census did not distinguish between improved and commom seeds and reports on the amount spent on insecticides and fungicides started in 1960.

The regional usage of fertilizers is presented in Table 41. The data presented include usage in the North and Central regions. Since usage in these regions were minor the inclusion of the data will have only a minor effect on the Northeast and South regions. The pattern of regional usage of fertilizers is very similar to the other variables already presented. The Northeast holds a share varying between 6.4 and 9.3 per cent with a tendency to decline through time while the South's share varied between 90.7 and 93.6 per cent. A factor in this distorted picture is that fertilizer manufacturing and mixing were concentrated in the South, mostly in Sao Paulo, and the imports come through Sao Paulo's port of Santos (Ruff and Missiaen, 1975:48). This situation also has the effect of decreasing the price of fertilizers for the South region at least by the amount of freight cost.

Tables 42 and 43 present prices of fertilizers for the two regions, respectively. Prices in the South are generally lower. Sao Paulo experienced the lowest price. Indeed, in 1975 Sao Paulo's price was 65.7 per cent lower than Ceara's price, a very large difference.

Data for seeds and pesticides are presented only for the census years of 1960, 1970 and 1975. Expenditures for seeds in the Northeast were 12.0 per cent of the expenditures in the South in 1960 and 4.5 per cent in 1975 (Table 44). This percentage decline would have

Table 42. Price of fertilizers in the South of Brazil by selected states, 1966-1975

Year	State			
	S. Paulo	M. Gerais	R.G. do Sul	Parana
			(cruzeiro/ton)	
1966	180.20	194.01	202.02	181.59
1967	183.40	203.70	204.10	203.63
1968	228.00	235.47	226.86	221.24
1969	260.30	280.31	249.94	245.09
1970	284.60	315.78	299.17	270.62
1971	355.20	369.85	365.55	310.08
1972	441.90	428.09	432.16	390.79
1973	547.20	482.56	523.87	500.87
1974	1431.90	1235.55	1214.30	1214.30
1975	1001.40	1478.27	1561.41	1569.00

Source: Silva, Fonseca and Martin (1979:219-37), Prognostico (1980:39).

Table 43. Price of fertilizers in the Northeast of Brazil by selected states, 1966-1975

Year	State		
	Ceara	Pernambuco	Bahia
		(cruzeiro/ton)	
1966	274.57	228.88	237.03
1967	280.72	284.19	259.79
1968	302.15	308.06	277.71
1969	316.04	354.19	292.56
1970	362.56	364.16	336.86
1971	-	382.09	363.18
1972	542.79	431.08	513.66
1973	565.65	449.48	503.41
1974	1397.84	985.30	1125.78
1975	1660.31	1425.30	1549.36

Source: Silva, Fonseca and Martin (1979:219-37).

Table 44. Expenditures in the Northeast and South of Brazil for agricultural seeds, for 1960, 1970, and 1975

Year	Region	
	Northeast	South
	(1000 cruzeiros)	
1960	703.9	5841.8
1970	32170.0	349102.0
1975	107587.0	2370822.0

Source: Censo Agropecuario do Brasil (1960, 1970, and 1975).

Table 45. Expenditures in the Northeast and South of Brazil for insecticides and fungicides, for 1960, 1970, and 1975

Year	Region	
	Northeast	South
	(1000 cruzeiros)	
1960	214.0	3825.8
1970	2008.0	296625.0
1975	116222.0	1865742.0

Source: Censo Agropecuario do Brasil (1960, 1970, and 1975).

been greater if the total expenditures were just for improved seeds. This decline increased interregional differences in TFP. Combined expenditures for insecticides and fungicides are presented in Table 45. The expenditures increased through time for both regions. Relative to the South the expenditures in the Northeast declined sharply in the sixties and then increased between 1970 and 1975. As a consequence for the 15 year period expenditures for insecticides and fungicides have not diminished in the Northeast relative to the South.

CHAPTER VI

SUMMARY, CONCLUSIONS, IMPLICATIONS AND LIMITATIONS

Summary of Results

Colonial history and resource and political considerations have created a dual economy in Brazil and this duality is reflected in the two major regions of the country, the South and the Northeast. In the thirties Brazil began a new era. A program of industrialization, based on import substitution, was implemented and the agricultural sector took on the role of providing cheap food for the urban population and a source of capital for industrial development. Events in this new era have tended to worsen the disparity between the South and the Northeast.

The basic purpose of this study was to measure the change in total factor productivity for Brazil's agricultural sector, and for the two major regions and to relate this change to the factors affecting it, through economic policies and market conditions.

The analysis was based on duality theory at an aggregated level. For the country the concept of value added as a restricted profit function was applied to measure the growth in total factor productivity. Because of data limitation the regional analysis was performed by using a dual cost function approach.

For Brazil's agricultural sector, elasticities of value added with respect to quantities of the primary inputs and prices of the intermediate inputs were estimated. The derived demand for the intermediate inputs was used to estimate the elasticities of demand with respect to prices and with respect to primary inputs. Shadow prices of the primary inputs were estimated. These shadow prices relationships provided information concerning the relationships among primary inputs. Finally, the yearly change in productivity was related to exports and agricultural credit in an attempt to explain growth in TFP.

In addition to regional growth in TFP, elasticities of substitution and price-demand elasticities for the primary inputs were estimated for the two regions to distinguish patterns of input substitution and use.

From 1950 to 1976, value added for Brazil's agricultural sector grew at a rate of 3.1 per cent. The weighted share of productivity growth attributed to growth in primary inputs was 2.0 per cent, and the residual of 1.1 per cent was the estimated total factor productivity growth over the period. Fixed capital grew at a rate of 4.0 per cent while land and labor increased at rates of 3.0 and 2.5 per cent, respectively.

Estimated elasticities of value added with respect to the normalized price of fertilizers and with respect to land had unexpected signs, the estimates were 0.33 and -1.44, respectively. The elasticities with respect to labor and capital were 1.49 and 0.64,

respectively. The estimated elasticity of demand for fertilizers with respect to own price was -0.70.

With the exception of labor, estimated shadow prices of each primary input were positively related to the amount used in production and not consistent with expectations. In addition, the shadow price functions showed substitutability among all the inputs.

The agricultural export sector has grown faster than the agricultural domestic sector. Greater concentration of machinery, modern inputs and research in the export sector was an important factor in explaining the differential growth rates observed.

The major intermediate input and the only one with adequate data for the analysis was fertilizer. Usage grew rapidly during the entire period. Analysis of complementary data showed that increases in modern inputs, such as pesticides, improved seeds, and research grew noticeably only in the seventies. Any influence of these inputs may have had during the last part of the time series (the seventies) would in part be confounded with fertilizer. As a consequence, the potential of these factors to influence TFP growth was not measured.

In the regional analysis the Northeast of Brazil experienced small and negative growth in TFP during the period 1960-75. The South had a small but positive growth. These results indicate that the Northeast is losing its efficiency and inequality between the two regions is widening. Substitutability-complementarity relations in the two regions also showed different patterns. Capital and labor were substitutes for each other in both regions but the elasticity for the

South was twice the size of that for the Northeast. Capital and land were estimated as substitutes in the South and complements in the Northeast. These results are consistent with an increasing modernization and a growing scarcity of land in the Southern region. Land and labor were complements in the South but substitutes in the Northeast, and reflected in part the peculiar institutional relationship between owners and sharecroppers in the Northeast.

The estimated own-price elasticities of demand indicate that demand for capital was elastic in both regions. Labor experienced unitary elasticity in the Northeast and an inelastic demand in the South. Finally, land had an elastic demand in the South and an inconsistent sign in the Northeast.

Conclusions and Implications for Policy

The growth in TFP in Brazilian agriculture has been reasonable but below some tropical countries with a poorer resource base, as shown by international comparisons, and Brazil has potential for further gains in agricultural productivity. Correct policies must be pursued to achieve them.

Modernization efforts in Brazil's agriculture have been directed toward the export subsector. Relative to agricultural credit the effect of exports on TFP has been greater, as indicated by the regression of yearly change in TFP on variables representing credit and exports. This fact has three implications. It creates a modern base for production of some commodities but it also generates an imbalance

between the export and domestic food sectors. This imbalance leads to shortages and inflation in the internal market. This fact also indicates that policies do affect productivity gains and that neglect leads to stagnation.

Agricultural credit did not show a noticeable effect on productivity. One should not extrapolate from this fact and recommend a halt in the flow of credit to agriculture. However, the credit program should be reevaluated and an effort made to determine whether credit is being used in ways consistent with the intent of credit policies.

Based on the elasticities of the SVA with respect to the primary inputs it has been verified that increases in the amount of capital and labor used in production have a positive effect on value added while land has a negative one. These results are consistent with other studies which have indicated an excessive use of land in Brazilian agriculture and would suggest that policies should be directed toward the use of labor and capital and to use existing agricultural land more intensively rather than opening new frontier land.

Fertilizer use has grown steadily without noticeable change in prices; however, use of modern inputs and research has been largely neglected. International comparisons show that modern inputs are too costly for Brazilian farmers. Developed countries have achieved gains in productivity through the use of modern inputs, and adapting their use to local conditions in Brazil remains a challenge.

On the regional level this study verifies that the Northeast is losing its efficiency in agricultural production relative to the South. There are great differences between regions in research efforts, rural credit, use of modern inputs and degree of specialization. The South gets increasingly larger share of all these inputs and has specialized in the production of highly profitable export crops. Modernization of production in the South gives higher yields for crops traditionally cultivated in the Northeast. Existing policies seem to increase rather than reduce interregional disparities.

According to the estimated elasticities of substitution capital and land are substitutes in the South. Therefore, the policy of subsidizing the acquisition of machinery in the South seems to be coherent with an agricultural system that has land as a limiting factor. Land and labor were substitutes in the Northeast. If the reasons given for this result are true, policies should be directed to improve the institutional relationship between owners and sharecroppers and the availability of wage-labor. From the point of view of a more even income distribution the process of hiring additional laborers should be encouraged rather than working existing hired labor longer hours.

Implications for Future Research

Several important aspects explaining changes in agricultural productivity were not a part of this analysis. Educational level of farmers, research and educational expenditures, land ownership

structure, and distribution of benefits from gains in productivity were such aspects.

The distribution of productivity gains among social classes is another important area of work in a dual system like that of Brazil. Data for such analysis remain quite scarce and it is hoped that this effort will provide some impetus to correct this situation.

Limitations of Data

Time series data for less developed countries are scarce. The sources are varied, and frequent interpolations and extrapolations have to be performed. This process introduces errors in variables estimated and creates estimation problems associated with such errors.

It is well known that capital should be measured as a flow of services. Lack of data precluded this operation and a stock concept was used. Data on labor useage were generally unavailable. The censuses provide only the number of persons employed. In such cases interpolations were required and labor was treated as a stock rather than a flow resource.

In the regional analysis of this study extrapolations were made for some items for the less complete census of 1960 and for value added by state, which was not calculated after 1970. Also the small number of cross-sections prevented the exploitation of alternatives error structure specification when pooling data from cross-section and time series.

APPENDIX A

TIME SERIES DATA

Table A-1. Value added for the agricultural sector in Brazil and the wholesale price index for agricultural products, 1950-1976

year	Value Added (million cruzeiros)	Price Index (1966-70=100)
1950	62.05	0.81
1951	70.64	0.94
1952	84.29	1.07
1953	103.87	1.20
1954	132.22	1.57
1955	166.80	1.76
1956	192.48	2.08
1957	233.78	2.21
1958	260.19	2.46
1959	367.48	3.22
1960	508.19	4.41
1961	716.29	6.06
1962	1283.72	9.65
1963	1981.08	15.97
1964	4100.18	31.88
1965	5833.58	45.39
1966	6843.89	64.39
1967	9029.56	80.17
1968	11539.99	94.06
1969	14336.31	114.26
1970	17126.63	147.09
1971	23973.35	184.34

Table A-1. Continued

1972	30560.09	225.38
1973	44270.55	268.30
1974	65657.43	347.22
1975	87820.90	430.55
1976	137703.18	684.97

Source: Conjuntura Economica (several issues).

Table A-2. Land area planted to crops and number of people employed in agriculture, 1950-1976

Year	Land (1000 ha.)	Labor (1000 workers)
1950	17775.0	10996.8
1951	17872.5	11251.4
1952	17998.9	11511.7
1953	19602.5	11778.2
1954	20883.0	12050.9
1955	21082.4	12329.8
1956	22468.9	12615.2
1957	23302.7	12907.2
1958	23660.6	13184.1
1959	24308.8	13482.3
1960	25230.6	15634.0
1961	27328.9	15984.8
1962	28510.8	16354.8
1963	29999.0	16733.2
1964	30770.0	17120.7
1965	31290.0	17517.0
1966	31910.0	17922.4
1967	32430.0	18337.2
1968	32950.0	18761.7
1969	33470.0	19195.9
1970	33984.0	17582.1

Table A-2. Continued

1971	34500.0	17989.0
1972	35020.0	18405.4
1973	35540.0	18331.4
1974	36060.0	19267.3
1975	36600.0	20345.7
1976	37630.0	20816.6

Source: Anuario Estatistico (several issues), Censo Agropecuario do Brasil (1950, 1960, 1970, and 1975). An exponential interpolation was used to fill in missing values in the labor series.

Table A-3. Real value of buildings for Brazilian agriculture sector, 1950-1976

Year	Value of Buildings (thousand of 1966-70 cruzeiros)
1950	55578.4
1951	57561.3
1952	59514.9
1953	61589.7
1954	63634.3
1955	65804.9
1956	68025.5
1957	70544.7
1958	72888.9
1959	75254.6
1960	77777.5
1961	80358.9
1962	83000.2
1963	85794.2
1964	88653.8
1965	91580.5
1966	94671.9
1967	97738.5
1968	102038.7
1969	104541.6
1970	108025.3

Table A-3. Continued

1971	111625.1
1972	115344.9
1973	119188.6
1974	123160.4
1975	127264.6
1976	131505.6

Source: Langoni (1974:appendix B). An exponential extrapolation was used for the period 1970-1976.

Table A-4. Value of tractor horsepower and working animals in Brazilian agriculture

Year	Horsepower	Animals
	(1000 cruzeiros)	
1950	283.0	10332.0
1951	602.0	11940.0
1952	865.0	12528.0
1953	1648.0	14947.0
1954	2867.0	18509.0
1955	4609.0	22545.0
1956	5633.0	28622.0
1957	7471.0	32786.0
1958	8980.0	38364.0
1959	22164.0	49703.0
1960	31630.0	70204.0
1961	44900.0	103434.0
1962	93488.0	168730.0
1963	228189.0	273169.0
1964	578717.0	651438.0
1965	927685.0	880177.0
1966	1212023.0	660365.0
1967	1730245.0	1522165.0
1968	2286854.0	1778767.0
1969	2790035.0	2091015.0
1970	3320772.0	2632631.0

Table A-4. Continued

1971	4496340.0	3428159.0
1972	6389661.0	4464080.0
1973	8073205.0	3465238.0
1974	11889391.0	4931136.0
1975	18368815.0	7106200.0
1976	36461758.0	8650422.0

Source: IPEA (personal communication), Anuario Estatistico (several issues).

Table A-5. Real price of fertilizers after subsidy and price index of machinery in Brazil, 1950-1976

Year	PF (1966-70 cruzeiro/ton.)	IM[a] (1966-70=100)
1950	287.00	0.61
1951	283.00	0.73
1952	279.00	0.80
1953	275.00	0.92
1954	271.00	1.23
1955	313.00	1.35
1956	321.00	1.72
1957	279.00	1.97
1958	280.00	2.33
1959	282.00	3.32
1960	227.00	4.12
1961	342.00	5.90
1962	389.00	8.61
1963	404.00	15.63
1964	389.00	28.67
1965	461.00	46.27
1966	367.00	61.23
1967	218.00	76.92
1968	206.00	100.30
1969	199.00	120.61
1970	201.00	140.92
1971	197.00	165.53

Table A-5. Continued

1972	237.00	192.00
1973	288.00	220.30
1974	422.00	284.92
1975	246.00	386.61
1976	154.00	503.38

a) PF stands for price of fertilizers and IM for machinery price index. Source: IPEA (Personal communication) and Conjuntura Economica (several issues).

APPENDIX B

REGIONAL CROSS-SECTIONS

Table B-1. Value added in agriculture in Northeast Brazil, by state, for 1960, 1970, and 1975

State	Year	V.A.[a] (1000 cruzeiros)
Maranhao	1960	9037.0
	1970	496828.0
	1975	660735.0
Piaui	1960	2718.0
	1970	156616.0
	1975	208284.0
Ceara	1960	9786.0
	1970	363894.0
	1975	483945.0
R.G. do Norte	1960	5855.0
	1970	134729.0
	1975	179177.0
Paraiba	1960	19835.0
	1970	267531.0
	1975	355971.0
Pernambuco	1960	13691.0
	1970	555632.0
	1975	738932.0

Table B-1. Continued

Alagoas	1960	4608.0
	1970	238272.0
	1975	316879.0
Sergipe	1960	3308.0
	1970	114967.0
	1975	152895.0
Bahia	1960	33836.0
	1970	1140896.0
	1975	1517286.0

a) V.A. stands for value added.
Source: Conjuntura Economica (several issues). The values for the year of 1975 were estimated using the growth rate of agricultural output for the region (Nordeste: Analise Conjuntural, 1980).

Table B-2. Value added in agriculture in South Brazil, by state, for 1960, 1970, and 1975

State	Year	V.A.[a] (1000 cruzeiros)
M. Gerais	1960	38696.0
	1970	1977996.0
	1975	12663495.0
E. Santo	1960	6007.0
	1970	339390.0
	1975	457009.8
R. de Janeiro	1960	15154.0
	1970	433923.0
	1975	584304.5
S. Paulo	1960	80202.0
	1970	3032162.0
	1975	4082995.0
Parana	1960	42783.0
	1970	2111747.0
	1975	2843599.5
S. Catarina	1960	14976.0
	1970	997984.0
	1975	1343847.0

Table B-2. Continued

R.G. do Sul	1960	41089.0
	1970	2944270.0
	1975	3964643.0

a) V.A. stands for value added.
Source: Conjuntura Econonomica (several issues). The values for the year of 1975 were estimated using the growth rate of agricultural output for the region (Nordeste: Analise Conjuntural, 1980).

Table B-3. Expenditures for land, labor and capital in Northeast Brazil, by state, for 1960, 1970, and 1975

State	Year	land	labor	Capital[a]
			(1000 cruzeiros)	
Maranhao	1960	1366.9	544.0	140.4
	1970	108556.7	29386.0	5787.8
	1975	934661.8	227081.0	45125.3
Piaui	1960	822.9	506.8	305.7
	1970	122518.5	24272.0	6044.3
	1975	726200.0	154225.0	32785.1
Ceara	1960	6081.1	1596.9	432.0
	1970	217851.6	71488.0	26835.9
	1975	1587775.3	333427.0	12641.6
R.G. do Norte	1960	7375.6	762.9	287.9
	1970	123515.5	25532.0	10961.9
	1975	947207.3	144503.0	84804.9
Paraiba	1960	4841.3	1268.8	227.2
	1970	239700.0	48706.0	14306.8
	1975	149268.7	219965.0	163405.2
Pernambuco	1960	4568.3	3656.6	755.8
	1970	145896.0	181400.0	35701.0
	1975	847372.0	711672.0	272615.5

Table B-3. Continued

Alagoas	1960	1632.1	1244.5	174.6
	1970	62593.3	81846.0	21695.5
	1975	385763.4	461740.0	256429.0
Sergipe	1960	4493.7	499.2	111.4
	1970	149294.0	25248.0	8701.6
	1975	371928.6	111524.0	55649.3
Bahia	1960	157100.0	4366.8	610.9
	1970	644320.0	191773.0	53111.3
	1975	5404111.1	1190664.0	344614.8

a) The missing items for capital expenditures in 1960 were estimated using the percentage increase from 1970 to 1975.
Source: Tables B-7, B-9 and Censo Agropecuario do Brasil (1960, 1970, and 1975).

Table B-4. Expenditures for land, labor and capital in South Brazil, by state, for 1960, 1970, and 1975

State	Year	Land	Labor (1000 cruzeiros)	Capital[a]
M. Gerais	1960	87807.4	8364.4	5461.3
	1970	5233722.2	404452.0	284118.2
	1975	19619639.0	2063763.0	2030656.0
E. Santo	1960	19926.5	791.4	536.2
	1970	2034307.7	41052.0	302351.9
	1975	12041455.0	230972.0	302351.9
R. de Janeiro	1960	9121.5	2454.0	1054.2
	1970	624689.6	112474.0	65657.6
	1975	1295752.5	431150.0	346017.5
S. Paulo	1960	78379.0	19017.1	12800.0
	1970	2851460.8	781607.0	767562.8
	1975	14266512.0	3317301.0	4266631.8
Parana	1960	39892.8	8765.4	6511.7
	1970	896271.3	279894.0	345344.4
	1975	13415871.0	1506160.0	2765539.3
S. Catarina	1960	4081.7	715.3	1429.1
	1970	226293.5	44062.0	133642.9
	1975	1725428.9	198170.0	651118.9

Table B-4. Continued

R.G. do Sul	1960	20262.6	3956.3	9198.2
	1970	975141.3	175287.0	788856.0
	1975	8676614.8	821134.0	5192958.0

a) The missing items for capital expenditures in 1960 were estimated using the percentage increase from 1970 to 1975.
Source: Tables B-8, B-10 and Censo Agropecuario do Brasil (1960, 1970, and 1975).

Table B-5. Unitary expenditure for land, labor and capital in Northeast Brazil, by state, for 1960, 1970, and 1975

State	Year	Pl	Pt (cruzeiro/item)	Pk[a]
Maranhao	1960	0.405	0.470	0.036
	1970	26.374	24.800	1.330
	1975	192.131	151.900	8.111
Piaui	1960	0.267	1.410	0.103
	1970	30.717	46.790	0.430
	1975	165.560	251.380	1.726
Ceara	1960	1.168	1.990	0.026
	1970	34.021	69.960	1.070
	1975	276.495	333.520	3.050
R.G. do Norte	1960	2.996	2.540	0.008
	1970	46.144	82.940	0.400
	1975	379.779	377.880	6.639
Paraiba	1960	1.676	2.290	0.007
	1970	74.018	83.310	0.790
	1975	479.782	277.090	2.431
Pernambuco	1960	1.367	2.890	0.026
	1970	37.814	160.780	0.690
	1975	198.021	625.530	3.491

Table B-5. Continued

Alagoas	1960	1.683	3.420	0.012
	1970	49.667	190.250	0.740
	1975	259.075	935.450	5.852
Sergipe	1960	4.916	2.000	0.021
	1970	122.412	83.960	0.970
	1975	264.210	273.860	4.276
Bahia	1960	9.729	2.390	0.014
	1970	56.375	90.210	0.570
	1975	389.269	472.690	2.776

a) Pl, Pt and Pk stand for unitary expenditure for land, labor and capital, respectively.
Source: Table B-3 and Censo Agropecuario do Brasil (1960, 1970, and 1975).

TABLE B-6. Unitary expenditure for land, labor and capital in South Brazil, by state, for 1960, 1970 and 1975

State	Year	Pl	Pt (cruzeiro/item)	Pk[a]
M. Gerais	1960	2.900	3.900	0.022
	1970	157.400	204.300	0.801
	1975	546.300	947.300	4.692
E. Santo	1960	12.600	2.800	0.045
	1970	806.100	137.000	1.720
	1975	4324.400	740.300	13.517
R. de Janeiro	1960	4.400	9.300	0.028
	1970	105.100	432.900	1.346
	1975	523.300	1548.100	6.045
S. Paulo	1960	5.300	11.000	0.018
	1970	176.000	550.400	1.004
	1975	694.000	2259.700	5.501
Parana	1960	6.500	6.800	0.023
	1970	97.100	141.300	0.560
	1975	1264.400	724.400	3.867
S. Catarina	1960	1.300	1.200	0.006
	1970	59.500	57.700	0.391
	1975	449.500	230.800	1.647

Table B-6. Continued

R.G.do Sul	1960	1.200	2.900	0.011
	1970	49.700	121.100	0.686
	1975	440.400	433.600	4.1833

a) Pl, Pt, and Pk stand for unitary expenditure for land, labor and capital respectively.
Source: Table B-4 and Censo Agropecuario do Brazil (1960, 1970, and 1975).

Table B-7. Rent paid to land and expenditure for interest and bank services charges in Northeast Brazil, by state, for 1960, 1970, and 1975

State	Year	R	IS[a]
		(1000 cruzeiros)	
Maranhao	1960	185.9	-
	1970	10530.0	1647.0
	1975	63557.0	22645.0
Piaui	1960	125.0	-
	1970	9924.0	1906.0
	1975	39941.0	14937.0
Ceara	1960	543.3	-
	1970	27885.0	6455.0
	1975	141312.0	48861.0
R.G. do Norte	1960	634.3	-
	1970	11981.0	3350.0
	1975	77671.0	24434.0
Paraiba	1960	643.9	-
	1970	19176.0	5486.0
	1975	99982.0	32816.0
Pernambuco	1960	548.2	-
	1970	18237.o	13049.0
	1975	72874.0	68067.0

Table B-7. Continued

Alagoas	1960	137.1	-
	1970	6736.0	6300.0
	1975	35876.0	53237.0
Sergipe	1960	71.9	-
	1970	2538.0	4124.0
	1975	5207.0	28088.0
Bahia	1960	1571.0	-
	1970	16108.0	18233.0
	1975	48637.0	116320.0

a) R stands for rent and IS for interests and service charges.
Source: Censo Agropecuario do Brasil (1960, 1970, and 1975).

Table B-8. Rent paid to land and expenditure for interest and service charges in South Brazil, by state for 1960, 1970, and 1975

State	Year	R (1000 cruzeiros)	IS[a]
M. Gerais	1960	4785.8	-
	1970	188414.0	73655.0
	1975	706307.0	471235.0
E. Santo	1960	976.4	-
	1970	52892.0	7812.0
	1975	132456.0	57479.0
R. de Janeiro	1960	1058.1	-
	1970	26838.0	9654.0
	1975	130871.0	63862.0
S. Paulo	1960	8621.7	-
	1970	290849.0	119722.0
	1975	913225.0	705501.0
Parana	1960	5026.0	-
	1970	168499.0	52011.0
	1975	1556241.0	256250.0
S. Catarina	1960	289.8	-
	1970	20819.0	14715.0
	1975	122509.0	154926.0

Table B-8. Continued

R.G. do Sul	1960	3094.0	-
	1970	179426.0	99736.0
	1975	1058547.0	775014.0

a) R stands for rent and IS for interests and charges.
Source: Censo Agropecuario do Brasil (1960, 1970, and 1975).

Table B-9. Loans to agriculture and expenditures for fuels in Northeast Brazil, by states, for 1960, 1970, and 1975

State	Year	Fuels (1000 cruzeiros)	Loans (1000 cruzeiros)
Maranhao	1960	6325.0	-
	1970	32251.0	27441.0
	1975	164446.0	270558.0
Piaui	1960	3591.0	-
	1970	10629.0	19483.0
	1975	31460.0	275269.0
Ceara	1960	4109.3	-
	1970	22150.0	57055.0
	1975	119393.0	454870.0
R.G. do Norte	1960	1456.4	-
	1970	7877.0	27859.0
	1975	42602.0	241830.0
Paraiba	1960	5069.5	-
	1970	16123.0	53477.0
	1975	84688.0	404063.0
Pernambuco	1960	4890.5	-
	1970	27717.0	104985.0
	1975	156798.0	756225.0

Table B-9. Continued

Alagoas	1960	4899.5	-
	1970	12776.0	52785.0
	1975	114179.0	683328.0
Sergipe	1960	1347.0	-
	1970	6710.0	34100.0
	1975	33407.0	264184.0
Bahia	1960	12162.0	-
	1970	60581.0	153710.0
	1975	301751.0	1555622.0

Source: Censo Agropecuario do Brasil (1960, 1970, and 1975).

Table B-10. Loans to agriculture and expenditures for fuels in South Brazil, by state, for 1960, 1970, and 1975

State	Year	Fuels	Loans
		(1000 cruzeiros)	
M. Gerais	1960	537.3	-
	1970	44914.0	536014.0
	1975	482928.0	4712230.0
E. Santo	1960	87.7	-
	1970	4862.0	54228.0
	1975	42770.0	543931.0
R. de Janeiro	1960	115.4	-
	1970	11258.9	77927.0
	1975	87155.0	603412.0
S. Paulo	1960	1918.0	-
	1970	146343.0	1001863.0
	1975	995244.0	7124772.0
Parana	1960	509.7	-
	1970	47519.0	514701.0
	1975	575335.0	5044099.0
S. Catarina	1960	57.4	-
	1970	12521.0	125149.0
	1975	127869.0	1244650.0

Table B-10. Continued

R.G. do Sul	1960	685.2	-
	1970	86337.0	800270.0
	1975	798047.0	6720336.0

Source: Censo Agropecuario do Brasil (1960, 1970, and 1975).

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He is married to Ana Carvalho and they have a son, Pablo.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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